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MARCH-APRIL
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FAULTING IN WYOMING OIL FIELDS

EDWARD L. ESTABROOK
Casper, Wyoming

The effect of faulting upon the accumulation and production of oil does not seem to have been very thoroughly studied and the literature of the petroleum industry includes very little information upon the subject. The writer ventures to present the following observations in order to record some of the data which the wonderful exposures of the Rocky Mountain Region make it possible to collect, with the hope that the paper will encourage discussion and possibly lead others to make public their records and thus finally assist in leading us all to a true perspective toward faulting in its relationship to petroleum geology.

The Elk Basin field is one of the best places in Wyoming in which to study faults, not only because the exposures are remarkably complete but because enough drilling has been done to make it possible to trace some of the faults in their underground courses. The field is located on the crest of a fairly symmetrical oval dome extending northwest-southeast for about fifteen miles with a width of about six miles. The average dip on the sides is about 25°–30° rising to a maximum of 60°.

The formations in which the faulting is observed include many hundred feet of alternating shales and sandstones from the Eagle sandstone upward, all belonging to the Montana group of the Upper Cretaceous. The closeness with which the bold escarpment of the

Eagle sandstone encircles the field makes it unusually easy to separate the faults which cut entirely across the crest of the fold from those which play out as they approach the top. The sandstones of the Frontier formation (Colorado group) lie at a depth of about 1,100 feet in the center of the field and are separated from the Eagle sandstone and the other competent beds above it by 1,900 feet of the moderately firm Pierre shales.

Oil is produced from both the First and Second Frontier sands. The First sand is about 100 feet thick but so fine grained and "muddy" that it is a small and inconsistent producer, though saturated over a very large area. Below the top of the First sand some 250 feet lies the Second, about 75 feet thick, a clean coarse sand well saturated with oil carrying considerable included gas. This sand has produced the greater part of the 6,250,000 barrels of oil that have been taken from the field.

Three series of normal faults occur, two of which are roughly parallel in strike and cut across the field from northeast to southwest, with the third series at right angles to the other two and more or less parallel to the axis of folding (Fig 1). The northeast-southwest faults with displacements down on the south side probably occurred first, the group with the same course but down on the north side second, and the northwest-southeast series with displacement down on the east are last. The relative ages of the two northeast-southwest series were determined by a study of minor fractures in the escarpment where the planes of the one series were found to have been displaced by those of the other. The time of the northwest- southeast faulting in relation to the first northeast-southwest movement is shown in the northwest quarter of Sec.31, T. 58 N., R 99 W., where the plane of one of the latter series is displaced 75 feet on the surface by a northwest-southeast fault. The evidence concerning the time of the other northeast-southwest movement is not entirely clear. No data have been obtained as to the time relations of the faulting to the folding movement which produced the Elk Basin dome.

Only two faults of the northwest-southeast series have been found. Their planes dip to the east at an average angle of about 65°, and the vertical throws vary up to 170 feet at various points

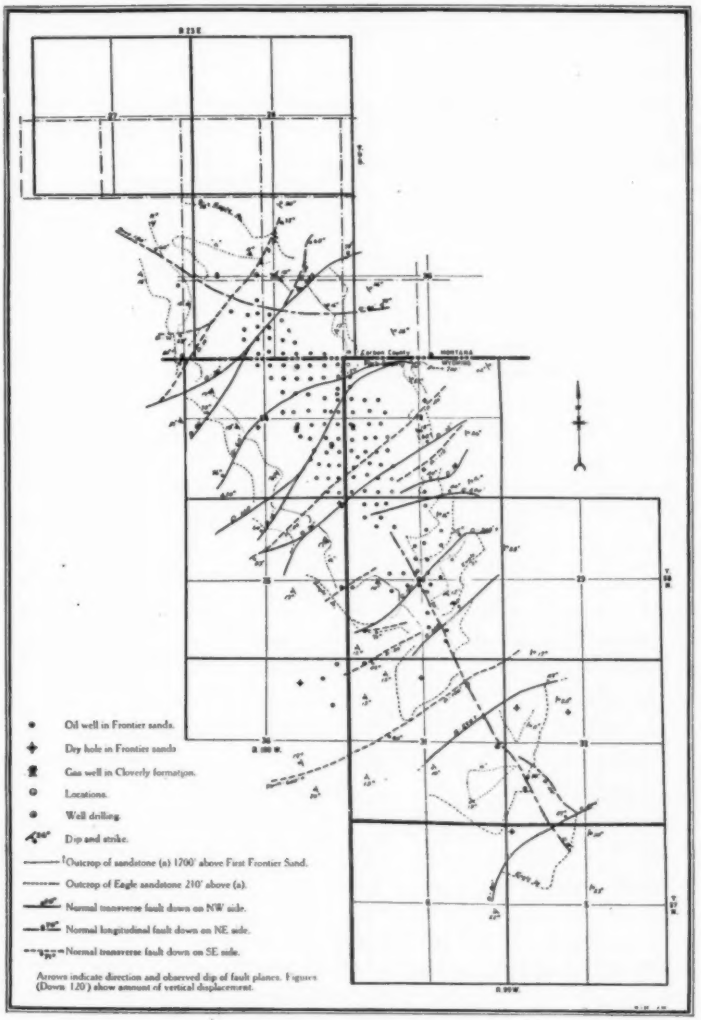
Oil well in Frontier sands.
Dry hole in Frontier sands
Gas well in Cloverly formation.
Locations.
Well drilling.
Dip and strike.
Outcrop of sandstone (a) 1700' above First Frontier Sand.
Outcrop of Eagle sandstone 210' above (a).
Normal transverse fault down on NW side.
Normal longitudinal fault down on NE side.
Normal transverse fault down on SE side.
Arrows indicate direction and observed dip of fault planes. Figures (Down 120') show amount of vertical displacement.

FIG. 1.—Map to show the faulting in the Elk Basin Oil Field, Park County, Wyoming, and Carbon County, Montana.

along their courses. Ten important faults belong to the northeast-southwest group with down-throw on the north. The dip of the planes to the north shows a progressive steepening as one passes from south to north. At the extreme south a dip as low as 27° has been observed, while four miles north, at a point a mile north of the apex of the fold, the average dip is as much as 75°. The vertical displacements vary up to 700 feet, the maximum in every case occurring on the northeast flank of the fold. Six or eight faults with northeast-southwest courses have the downthrow on the south side, The dip of the planes to the south varies from 45° to 68° but shows no progressive change within the area studied, which did not, however, extend as far north from the apex as it did to the south. The vertical displacements range up to 600 feet with maximum always on the southwest flank. At least two of the faults show a horizontal as well as a vertical displacement where they cut the First sand.

The question of the persistence of the faults with depth is a point which must be approached with caution. Eight of the faults at Elk Basin can be traced across the field from one escarpment to the other by observations on the outcrops at either end and by well logs in the center. Unfortunately, there are but few points where both well logs and surface data can be obtained close enough together to permit the displacement in the oil sand to be checked directly against that at the surface. The amount of the displacements changes so rapidly along the course of the faults that it is not possible to compare them at the sand and on the surface unless the one is directly below the other. Even then the comparison is open to question since the direction of greatest displacement may not be vertical but may follow some oblique angle determined by the nature of the forces causing the faulting and by the resistance of the beds involved, according to their character and attitude.

May this occasion be taken to express the hope that there may be a more general use, among petroleum geologists, of the word dip to describe the angle of a fault plane from the horizontal instead of using the word hade which refers to its angle with a vertical plane? All of the field observations of the position of strata are referred to the horizontal datum plane and it seems a desirable simplification to use the same datum in describing the attitude of the fault planes.

The study of faults in the Elk Basin field has assumed a larger importance since the summer of 1920 when the Ohio Oil Company brought in their Well No. 10 on Woods No. 3 Claim as a 400-barrel flowing well in the Second sand in a fault block almost cut off from the main pool by the downthrow on the north side of the fault. Wells are now being drilled to determine whether other productive blocks may not exist in the south end of the field.

In spite of the numerous faults no seepage of oil or gas has ever been found in the Elk Basin field nor has oil been encountered in faulted areas in the shale, as is common in Salt Creek and Teapot and sometimes reported in other Wyoming oil fields. Open and empty crevices of considerable size have been found in the shale above the oil sands, and recently one has been found in the shale 800 feet below the Second sand which was so large that several thousand barrels of mud were required to fill it.

The variation in productivity of First sand wells and the small amount of gas in the First sand oil, as compared with that from the Second sand, have led to speculation as to whether or not the First sand oil may have had its origin in the Second sand and have migrated upward along the fault planes to its present location. The question is still open and probably always will be. The variations in productivity in the First sand can be explained as being due to variations in the porosity of the sand. The migration theory is supported by the fact that the oil in the First sand extends down about 1,500 feet below the top of the dome before water is encountered, while in the Second sand it goes down only about 300 feet.

The more important lines of faulting in the Salt Creek field were located many years ago by C. H. Wegemann and shown on maps accompanying his report published by the United States Geological Survey in *Bulletin 670*. All of the faults known have a general east-west course at right angles to the axis of folding, the extreme variations in direction being from north 55 east to south 10 east, with the majority at about 85° east. Although careful search has been made no faults have been found with a course parallel to the longer axis of the fold. About forty faults have been mapped which cut the Shannon escarpment of Salt Creek or can be traced in the shales on Teapot dome. They all appear to be normal faults; about

one-third have their displacement down on the north side and two-thirds down on the south side. The two largest faults in the oil-producing territory have vertical displacements of something like 250 to 300 feet at the point of greatest throw. One of these large faults, in the extreme north end of the field, has its downthrow on the north side, while the other, in the saddle between Salt Creek and Teapot dome, is down on the south side. Both of these faults, and probably most of the others in Salt Creek, diminish rapidly in magnitude as one passes east or west from the point of greatest throw. On the question of changes in their magnitude with depth, not much information is yet available, but it appears that some of them at least continue with unabated intensity to a depth of 2,000 or 2,500 feet. Another point upon which the evidence is still scanty is that of the dip of the planes of the faults. It appears now that those down on the north side dip at angles of from 70° to 85°, while the planes of the series that are down on the south side have dips of only 55° and 70°.

Evidence as to the relative ages of the two series of faults can no doubt be obtained in many parts of the field but the best that has come to the attention of the writer is in the escarpment of the Shannon sandstone near the center of Sec. 3, T. 39 N., R. 79 W., where a fault plane with downthrow on the south is displaced by each of four parallel planes with downthrow on the north. At that particular point the evidence is clear that the series of faults down on the north is the younger of the two series. If this generalization is correct, the so-called block faulting in Salt Creek is rather an accidental condition due to a block of strata being near the downthrow side of two normal faults of different ages and opposite throw, which by their movements have left a V-shaped block lying below the surrounding level of the formations.

Now a word on the much-discussed question of the effect of faulting upon the productivity of Second sand wells in the Salt Creek field. It has long been the custom in the field to ascribe extra large productions to the fact that the well has struck a faulted place in the sand. This idea arose from two causes: (1) many wells have made large productions of oil from open crevices in the shale which undoubtedly must be ascribed to openings made by fault

stresses, (2) the large producers often happened to start or were deliberately located along the outcrop of a fault, marked as many of them are, by a line of vein calcite. If the fault upon which such a well is located had a vertical plane and cut the sand at or very close to the point from which the well was producing it would be permissible to say that the fault was at least partly responsible for the large production, but such vertical planes are very much the exception in the field and probably a well so located would not reach the sand within 1,000 feet of where it was cut by the fault. The writer is very suspicious of any reasoning based upon so false a premise. It is true that some of the largest wells in the Salt Creek field are located at points where large faults cut the Second sand, but, on the other hand, some of the larger wells in the field are located at a considerable distance from any fault which can be traced on the surface or detected from well logs. The drilling of the Salt Creek field has only begun, there being now only one well to every 60 or 65 acres of Second sand. With the development of the drilling program, many questions concerning the field such as this, and the effect of faulting upon the sand will be satisfactorily answered. Let us try to await those answers with open minds.

DISCUSSION

W. E. WRATHER: May I ask Mr. Estabrook whether the faults observed around the Elk Basin structure appear to have had any important influence on the existing water table? Is the water level found at varying depths between the several faults?

E. L. ESTABROOK: The faults do not appreciably affect the location of the water table in the Second Frontier sand. The water line is 50 to 100 feet lower at the ends of the structure than along the sides but that condition is common to most of the oil fields in Wyoming.

M. J. HOPKINS: I wish to indorse Mr. Wegemann's observation that there have been several movements in the faults at Salt Creek. He makes the observation that pieces of calcite are striated and show slide planes. Further, pieces of calcite have often been broken by movement of the fault and later recemented.

ELIOT BLACKWELDER: Are the faults local features of the dome itself, or are they regional in distribution? In other words, are they fractures probably formed at the time the dome structure was made?

E. L. ESTABROOK: I am unable to answer the question definitely. In fact, one of the objects of this paper was to present these local data in the hope that

it would stimulate interest and assist in the study of the regional problems. At present I am inclined to believe that the faults are local rather than regional.

E. W. KRAMPERT: The oil from two recently drilled wells in the Lost Soldier field is hot (120° F.), while in neighboring wells the temperature of the oil is normal (70° F). The two wells producing the hot oil are on separate distinct fault planes. Is there a possible connection between faulting and the temperature of the oil?

E. L. ESTABROOK: We need more data on this problem, before attempting an answer—more temperature records and more studies of the subsurface conditions in these faulted oil fields.

ERNEST MARQUARDT: Mr. Estabrook stated as one of the questions for which he desires to find an answer was whether the oil accumulation took place prior or subsequent to the faulting. I understand that in the Cat Creek field there are some small producing areas separated from the main producing area by barren territory, where the oil has accumulated down dip or plunge and where the updip closure has been made by a fault. The oil accumulation in these cases must have occurred subsequent to the faulting. Is there not some similar evidence in the Elk Basin field which will answer the question Mr. Estabrook desires answered?

E. L. ESTABROOK: We have obtained no such evidence yet but drilling now in progress in the south end of the field may yield some.

C. MAX BAUER: With regard to the relative age of the faulting and the oil accumulation in the Cat Creek field, it seems to me that all of the evidence points to the accumulation of the oil before the faulting occurred. The oil occurs in the domes along the axis of major fold. The faulting does not control the accumulation of oil, but it does, however, modify it in that fault blocks, or grabens, produce less oil than those blocks which are up-faulted. In other words, it seems that there has been some migration of the oil since the faulting, but that the main controlling feature of the structure is the folding and the minor doming.

It may be that the minor doming and faulting were almost contemporaneous and that the oil had accumulated along the main axis before the doming and faulting took place, but if there is any difference in time the faulting was certainly later than the accumulation. Migration has necessarily caused the higher blocks to contain more oil, but it has not caused the lower blocks, which were formerly part of minor domes, to be lacking in oil. Our recent subsurface map of Cat Creek, together with production figures on all the wells seems to indicate a communication between the first and second sands in certain wells, other wells do not show the communication. I do not mean to state that some of the faults are open for any great distance vertically, but I do think that the gouge along the fault planes contains enough sand in places to cause some migration vertically. In addition to this, there may be a more recent set of joint planes or fissures which have been formed subsequent to the faulting and furnish avenues for communication between the first and second sands.

SHOESTRING SANDS OF EASTERN KANSAS

JOHN L. RICH
Ottawa, Kansas

"Shoestring" is a name popularly given to those of the oil and gas pools of eastern Kansas whose length greatly exceeds their width. Some of these "shoestrings," not over ¼ mile wide, are known to extend for more than 5 miles, and others with a width of about ½ mile have been traced for over 15 miles.

Inasmuch as "shoestrings," far from being rare phenomena, constitute a large proportion of the oil and gas pools of eastern Kansas, it seems worth while to present some of the information about them which has been gathered in the course of the last three years, and to outline certain theories as to their origin and some of the methods which a geologist may use in tracing them.

DESCRIPTION OF SHOESTRING SANDS

In the following paragraphs, brief descriptions are given of several typical shoestrings which have come more or less under the writer's observation. These will serve as examples, but include only a few of those which are known.

Elsmore shoestring.—Figure 1 shows the Elsmore shoestring as of January 10, 1921, except for a strip of 1½ miles at the north end which is not shown. At that date the field was 5 miles long. For most of its length, the productive area is only 500 to 750 feet wide, but at the southern end the pool widens to about ½ mile. In the narrow part of the pool, the productive sand is about 40 feet thick, though test wells on either side find no sand. At the southern end, where the pool widens, the thick, narrow body of sand gives place to thinner beds at two or three levels separated by thin breaks of shale. The trend of the pool curves gradually from N. 45° E. at the southern end to N. 10° E. at the north. Cross-sections show that, in general, the sand thickens at the bottom

(Fig. 2). The producing horizon lies about 160 feet below the top of the Cherokee shale.

Production is determined entirely by the extent of the sand body. The "string" crosses minor structural features without effect on the production except that there is more gas on the parts that are structurally highest. The location and extent of the pool is in no way governed by local details of structure.

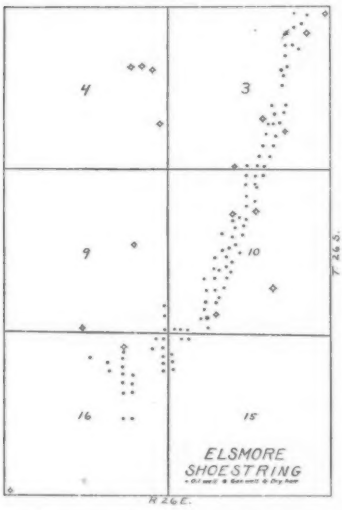

Fig. 1.—Elsmore shoestring as of January 10, 1921. The pool extends about 1½ miles farther north than shown. The south end was being actively extended.

Centerville shoestring.—The Centerville shoestring, Figure 3, is notable for its length, narrowness, and straightness. Its trend is N. 52° W. In its length of 5 miles, its width nowhere exceeds ¼ mile, and for most of the way is considerably less. For 3½ miles it is perfectly straight. The thickness of the sand ranges up to over 50 feet, while dry holes at the sides encountered no sand. The top of the productive sand lies about 15 feet below the top of the Cherokee shale. Details are not at hand as to the cross-sectional form of the sand body.

Erie shoestring.—Another shoestring trending about N. 60° W., remarkable for its straightness and narrowness, is found a few miles northwest of Erie, in T. 28 S., R. 19 E. In view of what is said later about delta distributaries, it is perhaps significant that this sand body trends toward a large area of scattered, irregular pools near Chanute.

Garnett shoestring.—In T. 20 S., R. 20 E., east and south of Garnett, is a long shoestring, Figure 4, which has been in course of development for several years. At present its southwestern end is being actively extended, and is proving to be a rich, though very

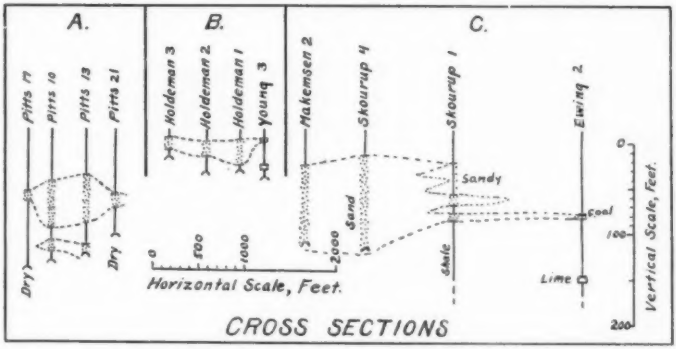

FIG. 2.—Cross-sections of shoestring sands. Section A, Elsmore shoestring. Shows thickening at bottom, indicating probable channel origin of the sand. Section B, a typical channel sand body. Sections 15 and 16, T. 23 S., R. 18 E. Note thickening at bottom. Section C, cross-section of east side of Colony sand body at Colony. Shows thickening at top and coal on east (lagoonward?) side, suggesting probable beach origin.

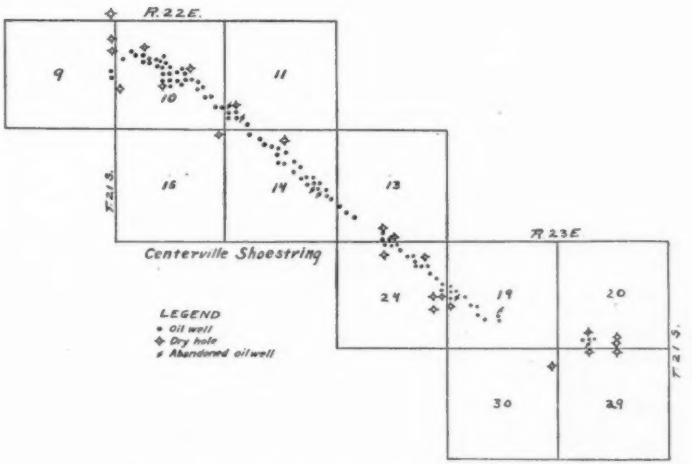

FIG. 3.—Centerville shoestring as of January 13, 1923

narrow, oil pool. The sand, which is 30 to 50 feet thick, lies about 30 feet below the top of the Cherokee shale.

This shoestring shows clearly the influence of structure, not in influencing the presence or the trend of the sand body, but in determining whether the sand contains gas or oil. On this "string,"

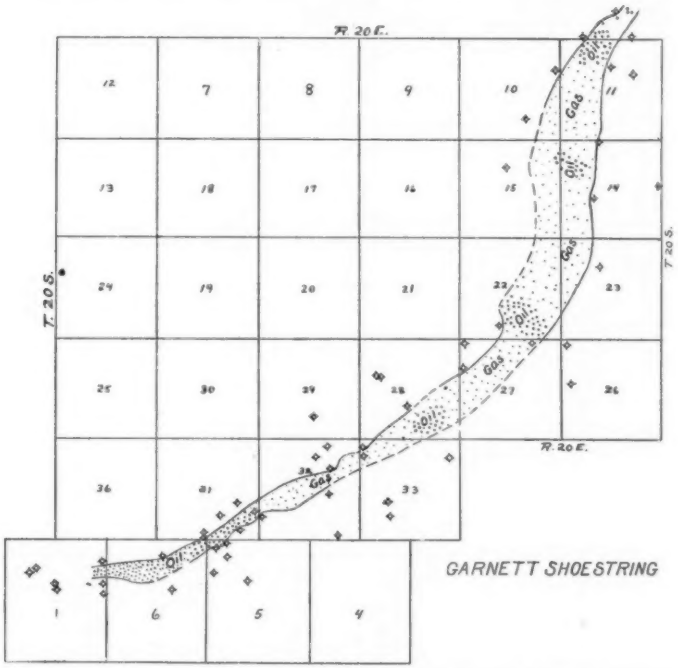

FIG. 4.—Garnett shoestring as of December, 1922. Heavy stippling shows areas where the sand yields oil; light stippling where it yields gas. In general, the oil is found where the sand crosses local synclines. Except at the western end, the boundaries, as shown, may be slightly in error because of lack of logs of all the wells. No attempt is made to show all the dry holes which failed to strike the shoe-string sand or the oil or gas wells obtaining production from other sands. The pool is being actively extended to the west. (Location of dry holes after map by Scott Tarbell.)

oil is found only where the sand crosses synclinal areas. Gas formerly filled the sand where the structure is anticlinal, but it is now almost exhausted.

The crescentic shape of this sand body is conspicuous and probably significant of sand-bar origin, as will be pointed out in following paragraphs. The splitting of the sand body into two or three beds, at the point of greatest bending in sections 22 and 23, is also

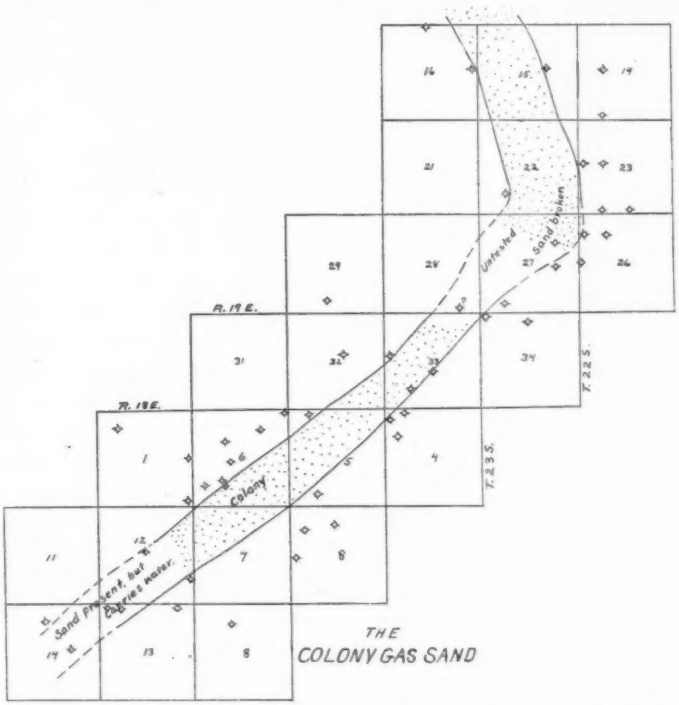

FIG. 5.—Colony gas sand as of December, 1922. Stippled area is producing gas. Dry holes which were too shallow to test the Colony sand, as well as oil wells obtaining production from shallower sands, are omitted. At the foregoing date the field was being extended northwestward.

suggestive of such origin. A cross-section at the west end shows thickening at the top.

Colony gas sand.[1]—The prolific gas pool, opened by the Teton Syndicate at Colony, T. 19 S., R. 23 E., Figure 5, has proved to be a

[1] Acknowledgment is made to the Teton Syndicate, which has permitted free use of its logs and other information.

shoestring of relatively large dimensions. The sand body, which at Colony is ½ mile wide and over 100 feet thick, has been traced for more than 15 miles. For a distance of 3½ miles along the main gas pool, its width scarcely varies and its sides are almost perfectly straight and parallel. On either side of the productive strip, wells miss the sand entirely or encounter only a few feet of non-productive, calcareous sand. The transition from thick sand and high production to thin sand and little or no production is very abrupt.

The relations of gas and water in the sand appear to be controlled by structure. The greatest accumulation of gas occurred where the sand crosses a prominent northwestward-plunging anticline. To the southwest, off structure, the sand contains water and a little heavy oil. Northeast of Colony, in the region where the sand body bends northward and then northwestward, the full thickness of sand is reported, but the gas yield is small and there is a little heavy oil in a small, local syncline. In this region, where the shoestring changes its trend, the sand is probably broken and non-porous, for there are scattered dry holes within the sand belt and the yield of producing wells is small, though the thickness of sand reported may be as much as 100 feet. Farther north, where the north-northwest trend becomes established, the capacity of the wells increases.

With respect to the sand body, the entire productive area appears to be anticlinal, for the sand ascends the regional dip from the southwest, turns north, parallel to the strike, and then northwestward, diagonally down the dip. Small synclines in the stretch where the sand parallels the strike are not filled with water.

RELATION OF OIL AND GAS TO STRUCTURE IN SHOESTRING SANDS

As has been noted in preceding descriptions of "shoestring" oil and gas pools, structure plays varying rôles in different pools. In some, it appears to have no effect; in others its influence is conspicuous. In general, it seems that structure is just as important in connection with shoe-string sands as with others, though the influence of minor structures in any particular instance may be masked by the larger structural relations of the sand body.

Long shoestrings, such as some of those described above, commonly cross several local structural highs and lows. If the shoe-

string sand in a particular locality carries water, it may be expected that oil or gas will be found where the sand crosses local anticlines and water will occupy the intervening synclines. If, however, as is common in the shallow fields of Kansas, the sands do not carry water, it has been the writer's experience that oil will be found where the sand crosses the synclines, and gas under low pressure, or dry sand, will be found on the anticlines.

In cases where a sand appears to be full of oil or gas irrespective of local structure, it is believed that the cause is to be found in the larger relations of the sand body to major structures or water levels, and perhaps also in the relation of the productive area to closed ends of the sand body.

It has been said by various geologists that structure is no guide to oil and gas in eastern Kansas, but that is only partly true. Given a prominent anticline, its productivity will depend upon (1) whether a suitable sand occurs at the point selected for a test, (2) whether the water conditions in that sand are such that oil or gas would be found on an anticline, even if the sand were present, and finally, (3) on the broader relations of the sand body to the general water circulation, or of the spot being tested to closed ends of the sand body.

As a result of these conditions, prospecting for oil or gas in a region of shoe-string sands is considerably more complex, from the geologist's standpoint, than in regions of sheet sands where structure plays the leading rôle in controlling accumulation.

One of the geologist's most difficult tasks is to determine the trend of a shoe-string sand after it has been discovered. This calls for the use of every resource at his command. If the origin of the sand body can be determined, the task is simplified, for sand bodies originating under different sets of conditions have quite different "habits." A coastal sand bar, for instance, will differ widely in section and pattern from a deposit made in the bed of a winding stream.

The first question, therefore, which is presented for solution when a shoestring is to be traced is: "What is its origin?" That question leads to a consideration of various possible ways in which long, narrow sand bodies may be formed and preserved, and of the distinguishing features of deposits of each type. This leads the

inquirer into the fields of paleogeography and sedimentation—branches of geology which are not yet fully developed, but about which enough is known so that tentative conclusions may be reached.

POSSIBLE ORIGINS OF SHOESTRING SANDS

In thinking of various ways in which sand bodies like the Kansas shoestrings may have been formed, the following have come to mind: (1) shore beaches and bars, (2) off-shore sand bars, (3) ordinary river channels, (4) delta distributary channels, (5) tidal channels.

Some of the characteristic features of each are listed below for comparison with features displayed by a shoe-string sand body under examination.

1. *Shore beaches and bars.*—Crescentic outline with occasional spits and hooks; smooth, sweeping curves; a thinning of the sand body seaward and thickening landward; fingering on the landward side and tendency for the sand body to lie stratigraphically higher on the landward side; relatively thorough assortment of material; possible irregular top caused by sand dunes; close association on landward side with muds, coal, or other lagoon deposits; thickening at top, at least with respect to the seaward side.

Another feature which may be expected in connection with crescent-shaped bars is a spreading and thinning of the sand body at the point of greatest bending halfway between the two horns of the crescent. Such a condition, noted in connection with the Garnett and Colony shoestrings, strongly suggests a beach origin for these bodies.

2. *Off-shore bars.*—Off-shore bars are thrown up during periods of severe storm at considerable distance from shore, where the storm waves drag on the sea bottom and break. Some of their characteristics are: relatively fine material; moderate thickness; poorer assortment of material; less distinctive shapes than shore bars; tendency to patchy distribution rather than long, sweeping crescentic curves as in shore bars; absence of typical lagoon deposits laterally from, or immediately above, the sand; a tendency to fine, even lamination of nearby deposits; and thickening at the top.

Off-shore bar origin is suggested for many of the lenticular sand bodies of the Kansas field which have not the distinctive narrowness of the beach and channel deposits.

3. *Ordinary river channels.*—Sand bodies formed by deposition in river channels should show some, or all, of the following features: cross-bedding typical of stream deposition; thickening at the bottom; irregular assortment of material; muddy sands; and remains of carbonaceous material. The ground plan of the deposit also may reveal its origin. The curves of a meandering river, where preserved, are unmistakable.

4. *Delta distributary channels.*—Meanders are by no means typical of all streams. Attention is here called to delta distributaries, which, of all river channels, are the ones most likely to have their channel-bottom sands preserved by a general settling of the delta.

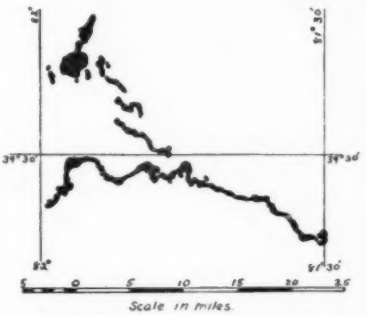

FIG. 6.—Oil pools in First Cow Run sand, near Marietta, Ohio. (After Ohio State Geological Survey.) Form suggests delta distributary origin for the oil sand.

If a large scale map of any good-sized delta is examined, it will be found that the distributary streams have nearly straight, rather than meandering, courses. Almost perfectly straight stretches of 5, 10, or 15 miles are by no means uncommon. If not straight, the distributaries usually bend in long, sweeping curves.

Outside the channel, the deposits are fine muds, perhaps with occasional thin streaks of sand. Finely laminated deposits such as are formed in open water are not to be expected. Narrowness, relative straightness, great length, and general uniformity should characterize a sand body formed in a delta distributary.

A series of oil pools in the First Cow Run sand near Marietta, Ohio, Figure 6, shows many features which suggest that their sands were deposited in delta distributaries. Note the branching, broad, open meandering, and the broader pool at the west probably lying where the supposed distributary entered open water.

Long, narrow shoestrings, like those at Erie and Centerville, extending at right angles to the general trend of the shore deposits, are believed to mark former delta distributaries.

5. *Tidal channels.*—Tidal channels may also form sand deposits which have nearly the same characteristics as those of delta distributaries. They are likely, however, to be more meandering, to branch more frequently, and to be shorter than distributary channels.

Combinations of types.—Theoretically it is to be expected that in some localities sand bodies formed in several ways would be found in close association. There might be, for example, shoe-string sands formed in delta distributaries which, if followed, would lead into beach sands where the distributary entered open water and its sediments were assorted by the waves. In such a case, there would be a general tendency for the deposits of the two kinds to trend in directions approximately at right angles to each other. Each should however present the distinguishing features outlined above.

TRACING SHOESTRING SANDS

If the geologist is called upon to guide prospecting for the extension of an oil or gas pool suspected of being in a shoestring sand, the first step should be to ascertain, if possible, whether the sand body in question is of the bar or channel type. If its composition and cross-section indicate that it is a sand bar, its probable trend can be judged by comparison with the trends of other bar sands which may be known in the vicinity at that horizon, or by comparison with the general trend of the shore line of that epoch if it is known. Another feature of sand bars—the crescentic form—must be borne in mind.

If the cross-section indicates that the sand body is a channel filling, the problem of tracing it is even more difficult, for until enough wells have been drilled to define the trend of the channel, there will be no clue to guide the prospecting, except, perhaps, the general probability that the trend will be more or less at right angles to that of sand-bar pools at the same horizon. The curves of a channel sand formed in a distributary or in a river bed, will not be a series of crescentic loops, but will have a general S shape, widely and gently curving if formed in a distributary; more or less closely looped if in a meandering stream.

Cores as an aid in tracing shoestring sands.—If the geologist is fortunate enough to persuade his client to use a core drill in prospecting and tracing shoestring sands, his chances of success are much greater than they otherwise would be, for the cores permit detailed study of the sediments at the critical horizon, and yield vital information as to the conditions of deposition, from which the geologist can determine the nature of the sand body with which he is dealing.[1]

SHOESTRINGS IN THE DEEPER FIELDS

Shoestring sands are by no means confined to the shallow fields of eastern Kansas. They are found also farther west in the state at much greater depths. The Sallyards pool, as described by Berger[2], is a typical example, and a number of others are already known. The methods of tracing shoestrings suggested above should apply equally in the deeper fields, with the added incentive to careful geological work and coring, which is given by the greater cost of drilling.

DISCUSSION

C. A. FISHER: Shoestring sands outcropping at the surface occur in the Goshen Hole district of eastern Wyoming and western Nebraska. Here the sand deposit occurs as a narrow zone 60 to 100 feet wide, meandering through beds of yellow Tertiary clays. The sand is cross-bedded, coarse grained, and somewhat muddy in places. These sand bodies can be traced in places from ½ to 1 mile. It is believed that a study of these deposits where they outcrop on the surface might lead to a better understanding of their occurrence underground.

ALEX. DEUSSEN: I would like to ask Mr. Rich, if there is no structure or faulting controlling accumulation in shoestring sands, what is responsible for the accumulation of oil in these sands?

JOHN L. RICH: It is my idea that two factors control the accumulation of oil and gas in the shoe-string sands: one is structure, the other is the pinching out of the sand bodies. If a shoestring crosses several local anticlines and synclines, the oil appears to have been trapped on the anticlines if the sand is water-bearing, and in the synclines if it is not. On the other hand, if a shoestring sand body pinches out, it is my idea that an accumulation of oil or gas may be expected near the end toward which the rock fluids are flowing. It is thus that I would explain accumulation in certain shoestrings where local structures appear to have no influence.

[1] A percussion core drill is now on the market which can be attached in a few moments to the rope socket of the ordinary churn drill.

[2] Walter R. Berger, "The Relation between Structure and Production in the Sallyards Field, Kansas," *Bull. Amer. Assoc. Pet. Geol.*, Vol. V (1921), No. 2, pp. 276–81.

NOTES ON CALIFORNIA OIL FIELD PRACTICE

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PROVED AREAS AND ACREAGES PER WELL IN CALIFORNIA OIL FIELDS

The oil fields of California, some thirty-eight in number, cover 109,392 acres of proved oil lands, according to the most recent classification of the Department of Petroleum and Gas of the California State Mining Bureau. Within this proved area 13,068 wells have been drilled, with an average allotted acreage of 4.2 acres per well.

Reference to the accompanying map (Fig. 1) shows the proved area of a portion of the Midway oil field in Kern County. It is apparent that a considerable portion of the oil land within this proved area is still undeveloped. This condition holds true in varying amounts for most of the fields of the state. The quantities of proved acreages in thirty-six producing fields are listed below (see Table I). This list does not include the two small fields, Moody Gulch and Half Moon Bay.

The quantities of developed acreages shown in Table I are determined by multiplying the average allotted acreage per well, drilled within the proved area of each field, by the total number of wells drilled to completion, whether producing, idle, or abandoned. On this basis the total developed acreage in California is 55,178 acres.

The spacing of wells varies greatly within each oil field, and, in arriving at the average allotted acreage per well, the spacing in numerous tracts of each field was determined, weighted by the acreages involved and averaged for the field. These field averages do not reflect nor emphasize the conditions of either maximum or minimum spacing, and, of course, the accuracy of the average acreage per well drilled depends largely upon the care and judgment exercised in determining sample spacings of various tracts in each field.

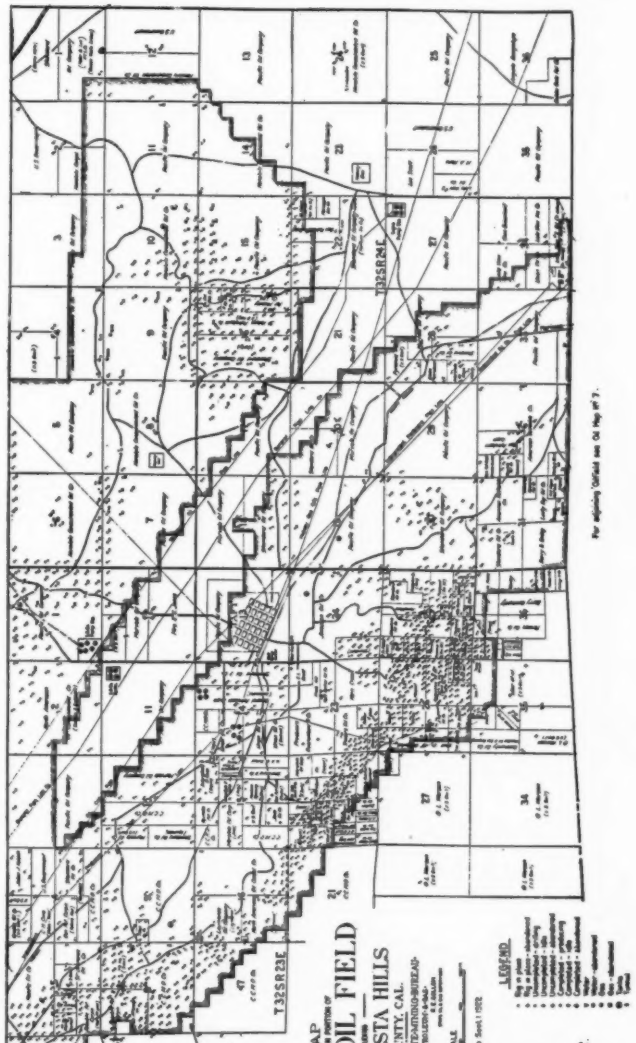
MAP
MIDWAY OIL FIELD
BUENA VISTA HILLS
KERN COUNTY, CAL.
T 32S R 23E
T 32S R 24E
LEGEND
Proved Oil Land
as of March 1, 1922.

FIG. 1

The following are a few examples of the variation in spacings or well areas. In the North Midway field the well areas vary from

TABLE I

PROVED AND DEVELOPED ACREAGES AND AVERAGE ACREAGE PER WELL, CALIFORNIA OIL FIELDS

County	Oil Field	Proved Acreages March 1, 1922	Number of Wells Drilled within Proved Areas	Average Acreage per Well Basis Average Spacing of Wells	Total Developed Acreage on Basis Average Allotted Acreage per Well	Undeveloped Acreage within Proved Areas
Fresno	Coalinga	14,365	1,723	6.1	10,510	3,855
Kern	Belridge	2,195	262	5.4	1,415	780
	Devils Den	30	26	.5	13	17
	Elk Hills	9,080	180	8.0	1,440	7,640
	Kern River	7,325	2,525	2.4	6,060	1,265
	Lost Hills	2,280	390	4.2	1,638	642
	McKittrick	1,655	421	2.0	842	813
	Midway	40,291	2,659	6.2	16,486	23,805
	Sunset	6,010	779	3.4	2,649	3,361
Los Angeles	Beverly Hills	110	20	5.0	100	10
	Long Beach	508	58	2.3†	123	385
	Montebello	1,160	177	4.5	797	363
	Newhall	380	137	2.7	370	10
	Salt Lake	934	317	2.5	793	141
	Santa Fe Springs	716	49	3.5*	175	541
	Whittier	564	252	2.2	554	10
Orange	Brea Olinda	1,963	571	1.7	971	992
	Coyote Hills	2,160	286	5.2	1,487	673
	Huntington Beach	2,151	235	3.2‡	752	1,399
	Richfield	1,292	175	4.4	770	522
Santa Barbara	Casmalia	1,920	112	4.8	538	1,382
	Cat Canyon	1,630	79	6.7	529	1,101
	Lompoc	1,193	37	19.4	718	475
	Santa Maria	4,600	287	10.5	3,013	1,587
	Summerland	120	387	.3*	120	.....
Santa Clara	Sargent	80	8	4.4	33	47
San Luis Obispo	Arroyo Grande	600	34	3.3	112	488
Ventura	Bardsdale	360	174	1.4	244	316
	Conejo	80	98	.5	49	31
	Ojai	420	89	2.8	249	171
	Piru	498	145	2.3	333	165
	Santa Paula	570	140	2.0	280	290
	Simi	606	69	5.8	400	206
	Sespe	451	84	3.4	286	165
	South Mountain	630	39	3.7	144	486
	Ventura	265	44	4.2	185	80
Total	.....	109,392	13,068	4.2§	55,178	54,214

* Partly town lots—some locations as close as three wells per acre.

† Partly town lots—some offset locations only 50 feet apart.

‡ About one-third town lots—many locations less than 100 feet apart.

§ Average acreage for California.

2.2 acres to 4.6 acres; in the Buena Vista Hills the average well areas are 9.5 acres and many tracts show 10 acres per well (Fig. 1). On the Twenty-five Hill area the average spacing is between 2.0 and

2.5 acres per well. The spacing of wells in the East Side Coalinga field varies from 3.0 to 10.0 acres per well, and on the west side from 2.4 to 8.0 acres per well. McKittrick and Kern River show the lowest acreages per well for the San Joaquin Valley fields. In the Coast fields Lompoc and Santa Maria show the highest acreages per well. In several of the larger tracts of the Santa Maria field wells are spaced 1,100 feet apart. In Ventura County the Bardsdale oil field shows the lowest acreage per well. Long Beach, Santa Fe Springs, and Huntington Beach oil fields in southern California show average acreages which obscure the minimum acreages brought about by town-lot drilling. For example, average acreages vary at Santa Fe Springs from 1.5 to 8 acres per well. Included within the data of the 1.5 acre minimum are town-lot tracts in which locations are as close as three wells per acre.

Up to July 1, 1922, the developed areas had produced 1,524,677,769 barrels of oil. The average recovery per acre for the state on July 1, 1922, is 22,170 barrels. The recovery per acre for a number of fields where segregated data of production, since discovery to July 1, are available, is as follows:

TABLE II

OIL RECOVERED PER DEVELOPED ACRE IN CERTAIN CALIFORNIA OIL FIELDS

Field	Production to July 1, 1922	Developed Acreage within Proved Area	Production per Developed Acre to July 1, 1922	Year of First Production
Casmalia Cat Canyon Santa Maria–Lompoc	107,867,127	4,798	22,500	1902
Coalinga	263,456,449	10,510	25,070	1896
Elk Hills Midway-Sunset	464,353,841	20,575	22,570	1900
Elk Hills only	32,331,845	1,440	22,450	1917
Huntington Beach	6,397,009	752	8,640	1920
Kern River	231,818,878	6,060	38,254	1900
Long Beach	3,889,201	123	31,620	1921
McKittrick	63,831,229	842	75,800	1898
Montebello	43,604,249	797	54,710	1917
Entire state	1,524,677,769	55,178	22,170	1875*

* 1894, outside Ventura County.

According to the estimates, the total undrilled areas amount to 54,214 acres for the present proved fields. In the Midway-

Sunset fields alone the proved area is 46,301 acres, of which 19,135 acres is estimated as developed, and therefore 27,166 acres as undeveloped. In Kern County the proved area is 68,866 acres. This includes 15,360 acres of Federal lands, mostly in Naval Petroleum Reserves No. 1 and No. 2, of which approximately 2,600 acres can be classed as developed.

In the Coastal fields, including those of Los Angeles and Orange counties, there is not such a wide margin between developed and undeveloped areas, and, although the new oil fields of southern California are now undergoing intensive development, it appears that the fields of central California, notably Midway and Elk Hills, still hold a large part of California's petroleum and gas reserve for the future.

In estimating the average acreages per well in any field as a whole, the spacing and number of offset locations of line wells causes a marked reduction in the average acreage, and the smaller the tracts held by different owners, the closer and greater in number will be the offset locations. This condition is emphasized, to the extent of becoming an actual menace to oil-field operations and the orderly and economic recovery of oil, in town-lot drilling.

TOWN-LOT DRILLING

During the past two years of intensive development at the Huntington Beach oil field, in Orange County, and the Long Beach and Santa Fe Springs oil fields, in Los Angeles County, the California operator has been confronted with a new problem, for California, namely: town-lot drilling. We have heard much of the evils of town-lot drilling and I will not therefore attempt to recapitulate them here. However, town-lot drilling should not be confused with close drilling or small acreages per well. The spacing of wells in several California fields, such as Kern River and McKittrick, are on an average basis of 2.0 to 2.4 acres per well. Here we have ten-, twenty-, and forty-acre tracts, or larger, in which wells were drilled according to more or less fixed plans of development.

In town-lot drilling, however, every well is in a sense an offset well, and offset wells are not drilled so much for the purpose of developing and producing that oil to which each operator has an unhindered right within his own lines, as to get the oil, lying under

each side of the boundary line, which will move to the well first drilled into the sand. This condition is one of the recognized fundamentals of oil-field development, and practically all leases carefully safeguard each lessor's interest as opposed to the adjoining lessor. The necessities of drilling offset wells, to meet lease requirements, is therefore one of the greatest contributory factors to forced drilling where small-property ownerships are involved. The principle of leaving certain quantitities of recoverable oil in its underground storage until the maximum profit can be obtained, and then bringing it to the surface by drilling the wells according to established oil-field practice as to spacing and careful methods of drilling, must be abandoned. Wells are raced to production and each new producing well calls for a number of offsets. One producing well recently completed at Huntington Beach on a "key" town lot imposed the immediate necessity of starting six offset wells on leases near by.

The economic result for the industry as a whole in California is this: Three new oil fields in California, Huntington Beach, Long Beach, and Santa Fe Springs, in which town-lot drilling plays a predominating part, were producing approximately 200,000 barrels of oil per day on October 1, 1922. These fields cover a proved area of 3,375 acres, 3 per cent of the total proved acreage of the state. For the first six months of 1922 the average production per day for California was 338,000 barrels, as against an average daily consumption of 293,000 barrels, making an excess, attributable partly to overproduction and partly to subnormal consumption, of 45,000 barrels daily. In July, 1922, two reductions were made in the price of crude at the well, and an earnest effort was made to curtail drilling activities wherever possible. One thousand producing wells, in various older fields, with an average daily production of 36,500 barrels, were shut in. The total production of the three new fields on July 15, 1922, was 106,000 barrels daily. Drilling in these fields continued without abatement, and on October 1, 1922, the total daily production was 200,000 barrels, almost two-thirds of the output of the state. As many wells are being reported ready to drill each week in October as were reported for the entire state, on a weekly average, during 1921.

Now these data are not being presented for the purpose of complaining about our local difficulties. California has its high and low points, like every other oil-producing district, in the inexorable workings of the law of supply and demand. It would seem possible, however, by careful study of development problems and intelligent effort, to level off some of the extremely high and low points in the curve. When we need the oil, as during the war period, we do not always know where to get it, or how best to drill to get the maximum output with minimum use of money, men, and materials. When we do not need the oil, we sometimes know where to get it, but that knowledge gets us more than we want, because we have not the proper economic machinery to call a halt.

The Long Beach oil field gives us an interesting example of what could be done in a high-pressure gas field to get a quick recovery by intensive drilling and properly directed close spacing. The results of intensive drilling at Long Beach, gauged by oil recovered per acre in other fields of the state, confirm the premise that close drilling and the bringing in of a number of producers, while gas pressures are high and before great quantities of gas, the expulsive force, have been wasted, will give a higher recovery per acre than where the oil is taken less hastily and the gas pressures become greatly reduced meanwhile.

On a tract of 18 acres at Long Beach, fifteen wells were producing on September 1, and eight wells drilling. The recovery per well at that date was 102,500 barrels and 91,000 barrels per acre. On a tract of approximately 56 acres thirty-three wells were producing, and thirteen wells drilling on September 1. The recovery per well at that date was 131,000 barrels—77,300 barrels per acre. It is possible that the ultimate recovery per acre will run as high as 150,000 barrels. I believe that this is not exceptionally high for ultimate recovery, as estimates range for some properties and fields in California. However, the proportion of the first year's recovery to the total will be very high, compared with recoveries in Table I, and, further, is detrimental to the industry as a whole at a time when the oil is not needed.

A remedy for town-lot drilling has been suggested for appropriate legislative enactment as follows:

It shall be unlawful for any owner of land or lessee from any owner of land or any agent or employe of any owner or lessee to drill or allow to be drilled any well prospecting for petroleum oil, gas or other hydrocarbon substances nearer than 125 feet from any exterior boundary of the land on which said well is located.

Nothing in this act, however, shall be constructed to preclude two or more owners of contiguous land from combining their properties for oil drilling purposes, in which circumstance all of the pieces and parcels of land so combined shall be considered as one parcel and all boundaries, saving and excepting the exterior boundary of the aggregate parcels shall be disregarded.

The means of enforcement is a matter for the legislature to decide, but the principle of controlled spacing should eliminate much of the economic evils of town-lot drilling.

THE ROTARY DRILL

The rotary drill has been considerably strengthened and improved, since it was first introduced into California from Texas, to meet the heavy duty of California conditions. Before California's recent plunge into the general use of the rotary—for almost all new drilling is being done with rotary—Texas seems to have held the record for deep rotary holes. For, according to the *Oil Age* of September, 1916, the deepest rotary hole in the world was on the property of Producers Oil Company, in the Humble pool. This hole was drilled to a depth of 5,410 feet. From 2,342 feet to bottom the hole was drilled in salt.

The record has been broken, however. Standard Oil Company drilled well No. "Packard" 1, Sec. 16, T. 31 S., R. 24 E., M.D.B. & M., to a total depth of 6,240 feet, using rotary tools. A wild-cat well was drilled in Sec. 34, T. 24 S., R. 19 E., M.D.B. & M., near Kettleman Hills, Kings County, using rotary tools from the surface to 3,500 feet, then cable tools to 4,070 feet, and then rotary to a total depth of 6,602 feet. Another well, No. "Baptist" 1, of Standard Oil Company, on Sec. 16, T. 30 S., R. 24 E., M.D.B. & M., Kern County, was drilled to a total depth of 5,909 feet with rotary tools.

The rotary is better adapted mechanically for making hole than cable tools, and apparently it can also compete favorably with cable tools for deep holes. However, something more than ability

to make holes is required properly to drill an oil well or develop an oil field.

The fundamentals of petroleum-development engineering and study of underground conditions in the oil fields of California are based upon the technique and observations of results of drilling with cable tools. Methods of excluding water from oil sands by use of sufficient casing, the principle of stratigraphically uniform water shut-offs, correlation of oil, gas, and water-bearing strata, and the ability to predict the depths at which they will be encountered in new wells, are all predicated upon accurate subsurface information.

The engineer has found that the rotary does not give this information as fully or accurately as the cable tool, and although we know the rotary has come to stay, it is being critically watched. If our knowledge and study and control of subsurface conditions in oil fields is to be maintained at the standard heretofore established, rotary-drilling practice should receive close engineering scrutiny and improvements.

It is a matter of common knowledge, for example, that a water sand is rarely detected or logged with rotary, oil and gas sands are passed up, the formation records are frequently vague and copiously padded with "shale and bowlders." Rotary "bowlders," by the way, are usually the evidence of mechanical interference with drilling, and not of a geological formation, and properly should not be logged in the formation record.

Referring to formation records: A comparison of the logs of three rotary holes and one cable-tool hole, between equal stratigraphic depths, shows that changes in formation were noted on an average of 36 times per rotary hole as against 73 times in a cable-tool hole. The average thickness of changes in formation for the three rotary holes is 57 feet as against 25 feet for the cable-tool hole. Details of this comparison are given in Table III.

It is not presumed that the cable tool gives an absolutely accurate record of stratigraphy, but the record is sufficiently accurate to be used in gauging the results of rotary work. In developed fields an accurate record of formations above the pay sand may not be so important, but let us compare those portions

of the logs of a rotary and a cable-tool hole after the drill entered the oil zone.

The sketch (Fig. 2), compares a rotary log and a cable-tool log between equal stratigraphic depths through the oil zone. Between

TABLE III

NUMBER OF TIMES FORMATIONS AND THEIR THICKNESSES, BETWEEN EQUIVALENT STRATIGRAPHIC DEPTHS, WERE IDENTIFIED IN THREE ROTARY HOLES AS COMPARED WITH ONE CABLE-TOOL HOLE

FORMATION	THREE ROTARY HOLES		ONE CABLE-TOOL HOLE	
	Number of Times Logged	Average Thickness (Ft.)	Number of Times Logged	Average Thickness (Ft.)
Surface sand	3	80	1	475
Yellow clay and sand	1	185	.....	.....
Yellow clay	3	45	.....	.....
Blue clay	14	49	9	25
Sand and bowlders	25	51	.....	.....
Yellow clay and bowlders	5	87	.....	.....
Blue clay and bowlders	32	94	.....	.....
Clay	1	55	3	14
Sticky blue clay	1	30	.....	.....
Blue shale	4	26	8	35
Sand and gravel	1	70	.....	.....
Hard sand	8	15	.....	.....
Sand	1	5	5	14
Shell	10	2.5	13	6
Water sand	1	11	3	20
Sandy blue shale	2	25	5	21
Sandy blue shale—oil	1	9	.....	.....
Sticky shale	1	10	.....	.....
Brown shale	.....	.....	3	13
Gray sand	.....	.....	3	42
Brown shale, show oil	.....	.....	2	9
Gray sand, show oil	.....	.....	1	25
Tar sand	.....	.....	1	40
Blue clay, little gas	.....	.....	1	10
Brown sandy shale	.....	.....	2	10
Adobe	.....	.....	1	5
White sand	.....	.....	3	40
Shale	.....	.....	8	21
Oil shale	.....	.....	1	12
Total	114	.....	73	.....
Average per hole	36	57	73	25

depths of 3,300 to 3,700 feet, twenty changes of formation and nine different formations are logged in the cable-tool hole, as compared with seven changes of formation and two different

formations between depths of 3,400 to 3,800–400 feet in each case, in the rotary hole.

Now some operators may say that, as long as you get the oil, what difference does it make whether all the formations are logged or not? It is granted that no great amount of engineering is required to drill a well which flows irresistibly as soon as the drill strikes "pay." That is a skilled mechanic's job. However, the flowing well of today is the pumper of tomorrow, and most wells have a monotonous future of ten to fifteen years ahead of them to

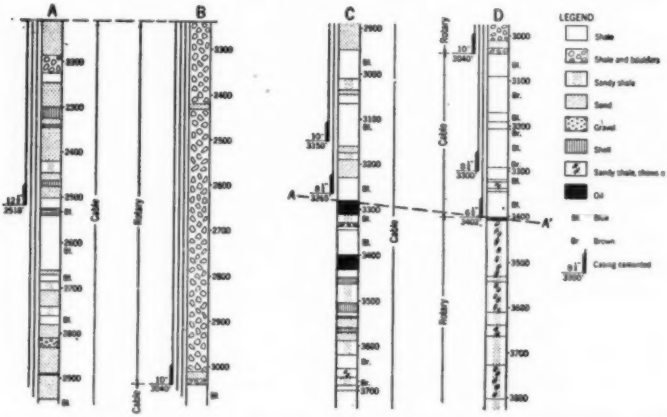

FIG. 2.—Sketch comparing a rotary log and cable-tool log between equal stratigraphic depths through the oil zone. (Courtesy U.S. Bureau of Mines.)

be interrupted only by cleaning-out jobs, redrilling, or plugging off water. If water invades the oil zone during that period, the driller will not be able to determine from such a rotary log where is a suitable formation in which to cement another string of casing or plug off bottom water. Future repair jobs, based upon getting contact with shales or shell instead of sand will be almost impossible.

This natural inability of the rotary to give an accurate formation record is being corrected by the use of the core barrel. The core barrel has been in general use in California for about a year and a half. It is constantly being improved, and is now considered indispensable for accurate work, Two general types of core

barrel are in use namely, single barrels and double barrels. Most of these barrels have been described in publications of the Department of Petroleum and Gas.[1]

The single barrel, the saw-tooth or basket type, was adapted from Texas practice. In deep holes expert manipulation is necessary on the part of the driller in order to get a good core and keep it from becoming burned or fused. Its advantages are cheapness of construction with a fairly good sample of material. Its disadvantages are danger from fusing core, contamination of the core with cuttings already at the bottom of the hole, and the necessity of drilling the hole to proper diameter after the core is taken.

The superintendent of one company using core barrels extensively in the Huntington oil field states that the company has attained remarkable efficiency in running the single core barrels by training drillers to take cores. Ordinarily the driller does not like to run a core barrel. He would rather be making hole.

When operating a single-barrel type core barrel, careful measurements of the location of the bottom of the hole is one of the main requisites. A driller, after some experience, will practically never burn the core barrel and the inclosed core. The core barrel will be run slowly and carefully until the required length of core is obtained, after which the drill pipe is dropped only enough to crimp the teeth of the core barrel. Usually this is not necessary, as, while drilling, the teeth will gradually crimp in, so that the core of solid formation taken is much smaller than the core barrel. The superintendent referred to above states that they have taken 147 cores without missing a single one. Formerly, it was a very common occurrence to run in and fail to obtain a core. This was due to the fact that the core barrel was given the full weight of the drill pipe, when running in to bottom, so that the teeth were bent

[1] R. E. Collom, "Notes on Core Drilling in Oil Fields," and R. M. Barnes, "Notes on 'Core Sampling' in Connection with Rotary Drilling as Practiced by Shell Co." in "Summary of Operations—California Oil Fields, "*Cal. State Min. Bur.*, Vol. VI, No. 12 (June, 1921); J. B. Case, "Notes on Use of Core Barrel with Rotary Tools" in *ibid.*, Vol. VII, No. 9 (March, 1922); J. E. Elliott and F. C. Merritt, "Core Drilling in Oil Fields of Southern California" in *ibid.*, Vol. VIII, No. 1 (July, 1922); W. W. Copp, "Notes on Improved Oil Field Tools" in *ibid.*, Vol. VIII, No. 3 (September, 1922).

in before starting to take core. The average time of running in, taking core, and pulling out at a depth of 3,000 feet, is four hours.

The following are tabulated cost data for taking core barrel samples at Huntington Beach oil field.

TABLE IV

COST OF RUNNING CORE BARRELS FOR SAMPLES AT 2,500 FEET

Wages per crew per hour	$4.187	
Wages of fireman	.655	
Fuel per hour	7.931	
Cost per hour		$12.773
Time—5 hours at $12.773 per hour	$63.86	
3 feet of junk pipe at 40 cts	1.20	
Shop labor	2.40	$67.46

DATA FOR GAS FIRE BOILERS

Time taking core at 3,000 feet with 4-inch drill pipe	4.2 hours
Time of drilling crew per core	$18.84
Time of welder curring core barrel—1 hour	.84
Acetylene for cutting core barrel	.35
Time of welder for making core barrel	.84
Acetylene in making core barrel	.35
Cost of pipe for core barrel	.60
Time of fireman (when fireman is used)	2.13
Fuel cost, gas	2.40
Water cost	.20
Electric light	.16
Cost of transporting barrel to and from rig	.66
	$27.37

NOTE.—There is a wide variation in these two costs and probably the foregoing is an average cost.

Several types of double core barrel are in use. These barrels have the advantage of greater strength of construction, more positiveness of action, take longer cores, and, as the outlet for the mud flush is close to the cutting edge of the bit, cores are not burned. The disadvantages are complex construction and for some barrels, as with the single barrel, the hole must afterward be drilled to a larger diameter. Where the core barrel is being used to locate a suitable shale formation in which to cement a string of

casing to shut off water, a long core is not as essential as a recognizable sample from an accurately determined depth.

It is possible that, as in many other departments of the oil business, the most effective use can be made of the core barrel by a concern that specializes in that kind of work. Such work is now being done in California by J. E. Elliott, of the Elliott Core Drilling Company, of Los Angeles. Mr. Elliott, a petroleum engineer and geologist, is a member of the American Association of Petroleum Geologists.[1]

The core barrel has been found particularly necessary and useful in drilling with rotary into the oil horizons of thinly bedded sand and shale of Huntington Beach, Long Beach, and Santa Fe Springs oil fields. In most cases, the depth of the top of the productive oil zone is actually determined by testing core samples with ether or chloroform. In some cases, of course, the cores give immediate physical evidence of oil (see exhibits). In many cases, it would be impossible to recognize the oil zone without the aid of the core barrel, the "iron geologist," as the driller calls it. The knowledge of this condition has raised the question as to whether we are sure there was no oil in all of those prospect holes heretofore drilled with rotary and subsequently abandoned because no showings were observed.

MUD FLUID

Now the rotary drill could not operate without continuously flushing mud fluid through the hole. The three principal functions of the mud fluid are: (1) to wall up the hole and prevent caving of loose material; (2) to convey cuttings out of the hole; and (3) to keep the bit cool.

Its fundamental purpose is to wall up the hole and cover formations. This is directly and effectively accomplished by filtration of mud into the porous strata under stratic pressure, and the mud flush as directly and effectively prevents the driller from getting information as to the nature and content of formations penetrated by the drill. We all know that the driller is able to recognize changes of strata by the action of the tools, but these mechanical indicators of lithology have marked limitations.

[1] J. E. Elliott, "Core Drilling in California," this Bulletin, to follow.

The three principal functions of mud fluid that I have mentioned are very necessary ones. The uncontrolled, or little observed, secondary functions of mud fluid in a rotary hole are deserving of a great deal of study and improvement.

We know that mud fluid has a higher hydrostatic value than water. Mud fluid is commonly described as thick or thin, heavy or light. It is pumped from a pit down through and out of the drill pipe, picks up its burden of cuttings, contributes its quota of mud to the walls of the hole, travels to the surface, and is caused to flow through a ditch so that its burden of sand and cuttings can drop out before it is pumped back into the hole.

The average rotary muds used in California practice range in specific gravity of 1.1 to 1.2, or, in weight, 9.2 to 10.0 pounds per gallon.

To increase the weight of the mud, and hence its hydrostatic value, we must increase its clay content; but, in adding more clay, we greatly increase its viscosity or thickness. Although for walling up formations heavy mud fluid is desirable, at the same time it is also desirable to hold the fluid to a minimum viscosity so that it will drop cuttings and sand rapidly; for, operators say, a burden of sand and cuttings much in excess of 3 per cent by weight may cause drill pipe to freeze.

For drilling through formations not to be produced, mud fluid should be of maximum weight and fluidity. When rotary tools are used for drilling the well into production the fluid should have minimum weight, consistent with security to the hole, and minimum fluidity. In drilling into the oil, it is desirable that as little mud as possible penetrate the sand, otherwise, when the well is ready to come in, some difficulty may be experienced in getting the sand to clean itself.

Two means of giving maximum weight to the fluid present themselves. One is mechanical, that is, by mixing some heavy mineral, such as iron oxide, as reported by Stroud;[1] the other is chemical, by increasing the clay content and at the same time decreasing the viscosity by adding certain reagents, such as sodium silicate, sodium carbonate, or ammonia.

[1] B. K. Stroud, "Mud-Laden Fluids and Tables on Specific Gravities and Collapsing Pressures," *La. Dept. of Conservation, Technical Paper No. 1*, March, 1922.

In drilling through high-pressure gas strata it is also desirable that the mud fluid be of low viscosity. Otherwise, the mud becomes quickly gas-cut; it is soon lighter than water; its static value is destroyed, and drilling becomes exceedingly hazardous.

At present, in the field, the weight of the mud fluid, determined by weighing an exact gallon, is used as the indicator of correct consistency. Several operators require the mud fluid to be kept mixed to a constant weight of 9.5 pounds per gallon, or 70 pounds per cubic foot. For the purposes already discussed, the weight or specific gravity truly indicates only its hydrostatic value. Mud fluids of the same weight may have high or low sand content and vary greatly in viscosity, and therefore weighing the muds alone will not give sufficient information properly to regulate them.

A suggested outline of laboratory determination of the physical properties of mud fluid is as follows:

1. Specific gravity by weighing a known volume.
2. Sand content by centrifuge test.
3. Rate of settling of mud by measured volume in calibrated jars.
4. Viscosity by use of MacMichael viscometer.
5. Means of increasing colloidal properties by use of reagents.
6. Mechanical means of eliminating sand, cuttings, and gas.

Another phase of handling mud fluid in the field, which should be improved, is the classifying or separation of sand and cuttings from the fluid. The rotary ditch used for this purpose in California practice is a wooden launder about 2 feet wide and 70 to 100 feet long with several right angle turns. It has a fall of about 1 foot per hundred and the sand and cuttings are supposed to drop out in this ditch as the mud stream flows slowly through it. Unless the ditch is kept clean of sand and cuttings its open cross-section is continuously diminishing with consequently a more rapid flow of fluid. When the tools are digging rapidly in sand, much of the sand is held in suspension after the fluid passes out of the ditch and back to the pumps.

Several operators are now working in an experimental way with mechanical classifiers. A Denver engineering concern is also working on this problem in an experimental co-operative way with a large California operator. The purpose is to perfect a semi-

automatic device which will not only rid the mud fluid of sand and cuttings, but will liberate the occluded gas in gas-cut mud. A revolving screen (Fig. 3) through which the mud fluid passes is being used at several wells by the General Petroleum Corporation, Pacific Oil Company, Oak Ridge Oil Company, and Shell Company. Shell Company used mud weighing 70 pounds per cubic feet, and Oak Ridge Oil Company uses 80-pound mud. In the mud pit, alongside the classifier, is a conical-shaped float or "hydrometer," which is designed to work automatically and regulate a water supply

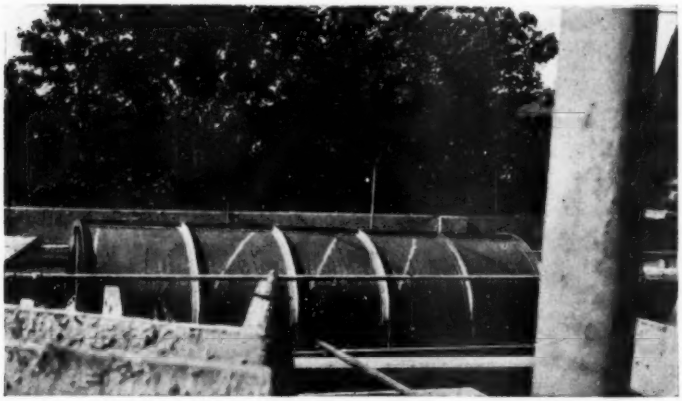

FIG. 3.—Revolving screen for ridding the mud fluid of sand and cuttings and liberating occluded gas. Cone-shaped hydrometer shown in center foreground.

in order to keep the mud fluid at a constant weight. The screen classifier, although not yet satisfactory in all particulars, is a step in the right direction, for, by such mechanical and almost automatic classifying, clean mud fluid of a constant weight will always be returned to the drill hole. The variable of sand burden will be eliminated and that will bring us one step closer to either physical or chemical control of the colloidal properties of mud fluid. The ultimate purpose of the engineer should be to emphasize, direct, and control the desirable qualities and functions of mud fluid and to minimize or eliminate, if possible, those qualities which are detrimental.

THE OIL FIELDS OF THE RAWLINS-LOST SOLDIER DISTRICT, WYOMING

E. W. KRAMPERT
Cheyenne, Wyoming

INTRODUCTION

During the season of 1922, development work in the proved Little Lost Soldier field has proceeded rapidly, and in potential production it is now second in the Rocky Mountain region only to the great Salt Creek field.

The first producing oil well in the field was drilled in, on June 29, 1916, at a depth of 265 feet. The estimated initial production was 200 barrels, coming from the top member of the Frontier formation. More wells were drilled during 1916 and 1917, some with initial production reported as high as 700 barrels per day. The limits of the field were established and less than 200 acres shown to be productive in this first sand. A deep test was started in 1916, but was abandoned before reaching the Mowry shale-producing horizon, and it was not until August, 1919, when the Bair Oil Company well No. 22 was drilled into production below the original discoveries in the Frontier horizon.

The Rawlins-Lost Soldier district, broadly defined, embraces all of a large uplift centering in the Rawlins Hills, where the granite basement of the region is exposed. The district is bounded on the north by the Ferris Mountains, on the south by a Mesaverde-filled syncline a few miles south of Rawlins, on the east by the Tertiary-filled Hanna basin; and on the west by the Tertiary-filled Great Divide basin. The district is divided into two parts by a shallow east-west syncline, through the center of T. 24. The part to the north of this syncline is the Lost Soldier district and contains all of the producing fields (Fig. 1).

The region received its name from the Lost Soldier dome, which occupies a small area near the old stage station of Lost Soldier.

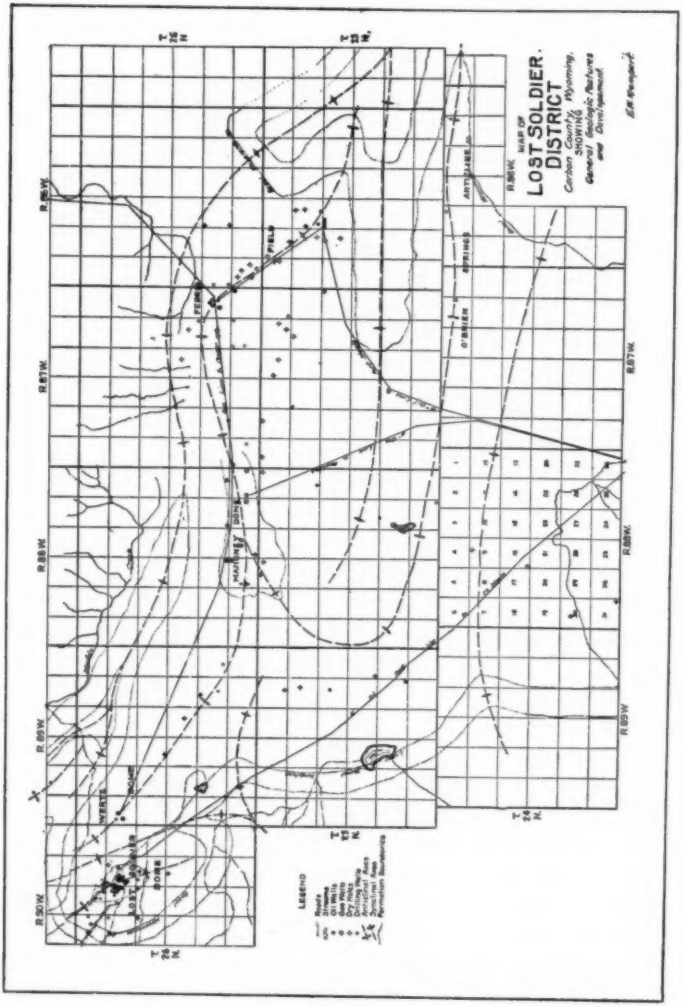
MAP OF
LOST SOLDIER
DISTRICT
Carbon County, Wyoming,
SHOWING
General Geologic Features
and Development
E.W. Krampert
LEGEND
Roads
Streams
Gas Wells
Oil Wells
Drilling Wells
Abandoned Wells
Dry Holes
Permian Outcrops
LOST SOLDIER
FIELD
SPRINGS
O'BRIEN
WERTZ
FIELD
LOST SOLDIER
DOME
R.89W.
R.88W.
R.87W.
R.86W.
T.25 N.
T.24 N.
T.23 N.

FIG. 1

To avoid confusion of names the producing Lost Soldier structure is now called the Little Lost Soldier dome (Fig. 2).

The Little Lost Soldier dome is on the main Rawlins-Lander road, about 40 miles northwest of Rawlins in T. 26 N. R. 90 W., Sweetwater County. It is about 90 miles from each of the towns, Lander, Riverton, and Casper, and can be reached from all of these places as well as from Rawlins over automobile roads which are good in the dry season.

This paper embodies the results of studies made by the writer in the field as geologist and petroleum engineer for the Bair Oil Company, and the Kasoming Oil Company, from 1919 to date.

HISTORY OF DEVELOPMENT

The writer has not been able definitely to determine just who was first responsible for drawing attention to the Little Lost Soldier dome as a probable producing oil field. It seems that locations under the old Placer Mining Law were first made by parties connected with the Ohio Oil Company, but their geologist is said to have reported unfavorably, and no development work was done. W. M. Armstrong and associates appear to have been the next locators, sometime in the early part of 1915, but they made no attempt to develop the field, and in May, 1916, W. H. Taylor relocated for Funk, Cochran, Clark, and others. Funk immediately proceeded to develop the property, but was stopped by injunction proceedings of W. M. Armstrong. A compromise was reached which resulted in the organization of the Bair Oil Company. Mr. F. O. Funk was put in charge of development work and brought in the first well on June 29, 1916. Immediately a great deal of the territory to the east was located and several other structures including the Mahoney and Ferris domes were worked out by geologists.

In September, 1917, a controlling interest in the Bair Oil Company was acquired by Messrs. West and Hazlett, who later became the incorporators of the Kasoming Oil Company.

In 1917 development work began on Ferris dome and a discovery of oil was made in the Mowry shale horizon at 1,575 feet on Sec. 25, T. 25 N., R. 87 W. Soon after a large gas well was drilled in at a somewhat greater depth in Sec. 26, by the same company.

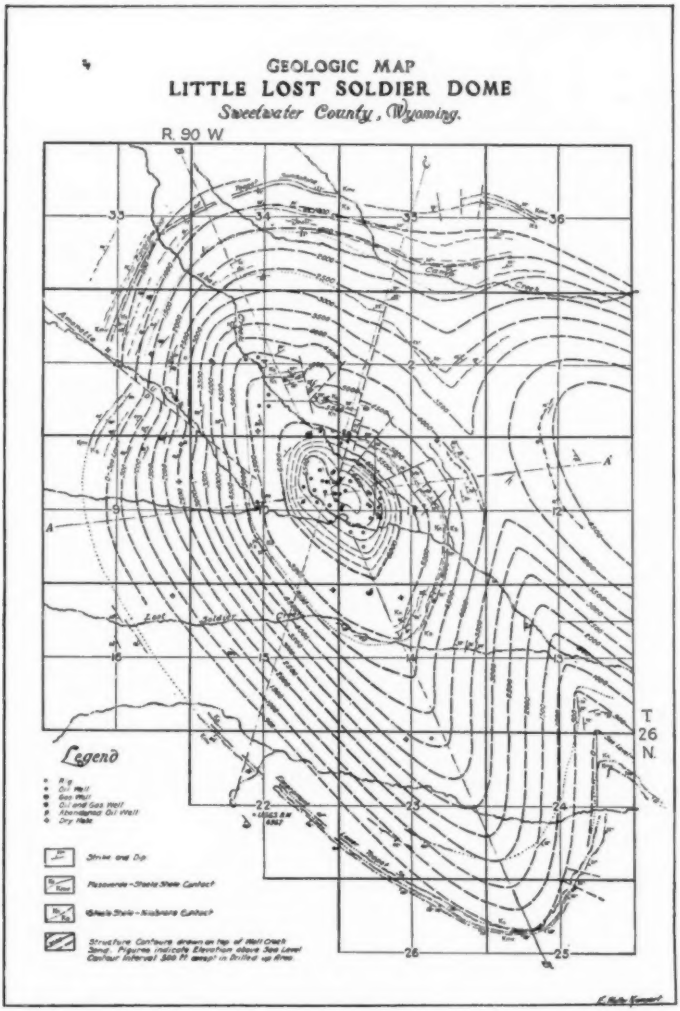
GEOLOGIC MAP
LITTLE LOST SOLDIER DOME
Sweetwater County, Wyoming.
R. 90 W
T. 26 N.
Legend

FIG. 2

During 1916–17 the Midwest Refining Company drilled the first well on Mahoney dome. This well was not drilled to the Dakota sand, but was abandoned after passing through the Frontier formation, and finding the sands barren.

In the fall of 1918 the Kasoming Oil Company started a well on Mahoney dome, and in the following year unexpectedly drilled in a very large gas well in the Dakota sand at a depth of 2,160 feet. The rock pressure was 825 pounds per square inch, and the production estimated at about 40 million cubic feet open flow. Before the well could be shut in, it caught fire from some unknown cause and burned for six weeks. The well was finally shut in early in 1920. After completing their No. 1 gas well the Kasoming Oil Company located another well northwest of No. 1, with the intention of prospecting the field for oil below the gas. The Dakota sand in the second well was found at a depth of 2,490 feet, and yielded 25 to 30 million cubic feet of gas. The next attempt was more successful as the Dakota sand was reached at approximately 2,750 feet and found to contain some oil.

The Ohio Oil Company has three gas wells on Mahoney dome at the east end of the field. The Producers and Refiners have two gas wells, one of them offsetting Kasoming No. 1, and the other offsetting Ohio No. 1. The Midwest Oil Company drilled a second well at the south end of the field which was a failure. The Dakota sand contained water with minor quantities of oil and gas.

In September, 1920, the Producers and Refiners Corporation drilled in a big gas well on the Wertz dome, $2\frac{1}{2}$ miles east of the Little Lost Soldier dome. The original rock pressure of this well is said to have been 1,840 pounds, and the open flow about 40 million cubic feet. A gas line to Casper was completed in the winter of 1921-22, and the Wertz well production turned in to supply the Standard Oil of Indiana refineries. This one well practically supplies the entire requirements of the refinery or about 30 million cubic feet. A simple system of drips at the well extracts approximately 100 barrels of gasoline per day.

After an extensive drilling campaign the General Petroleum Company brought in two or three small oil wells southeast of the Ferris dome on what has been locally called the G. P. dome. It

is the writer's opinion that this production comes from a lenticular shaly sand near the base of the Steele shale, which lies 1,385 feet above the Wall Creek sand. He does not believe that this field is located on an anticlinal high, but rather is on the southeast plunging axis of the Ferris dome. Almost all of this part of the Lost Soldier district is covered with wind-blown sand so that surface indications of structure are almost entirely lacking.

South of the G. P. dome on what is known as the O'Brien Springs anticline the Ohio Oil Company is putting down two wells. One of them reached the Wall Creek sand at approximately 3,100 feet with quite a good showing of gas. They are attempting to put down the hole to the Dakota which may be expected at approximately 4,400 feet.

GEOLOGY

STRATIGRAPHY

In the Lost Soldier district all of the formations from late Tertiary down to and including the granite basement are exposed. (See accompanying table.) The best exposures are obtained on the south flank of the Ferris Mountains where all of the formations up to and including part of the Mesaverde may be examined within a few miles. At Bell Spring and Browns Canyon, there are good exposures of practically the entire series. The youngest producing formation is probably a sand near the base of the Steele shale, belonging to the Colorado group, Cretaceous. The next lower producing sands are the various members of the Frontier series known as Wall Creek sands, also in the Colorado group.

Some production has been developed in the Ferris, Wertz, and Little Lost Soldier domes, from what appears to be the upper and harder part of the Mowry shale of the Colorado group.

The principal production in all of the fields is from the Dakota sandstone of the Cloverly formation.

The lower sand of the Cloverly which the writer has called the Lakota, after Darton, has not been drilled into at the Little Lost Soldier and Wertz domes. It was absent in No. 1 well drilled by Kasoming Oil Company on Mahoney dome and may be lacking in the Ferris dome. He is of the opinion that the Lakota will be a prolific producing sand in the Little Lost Soldier and Wertz domes (Fig. 3).

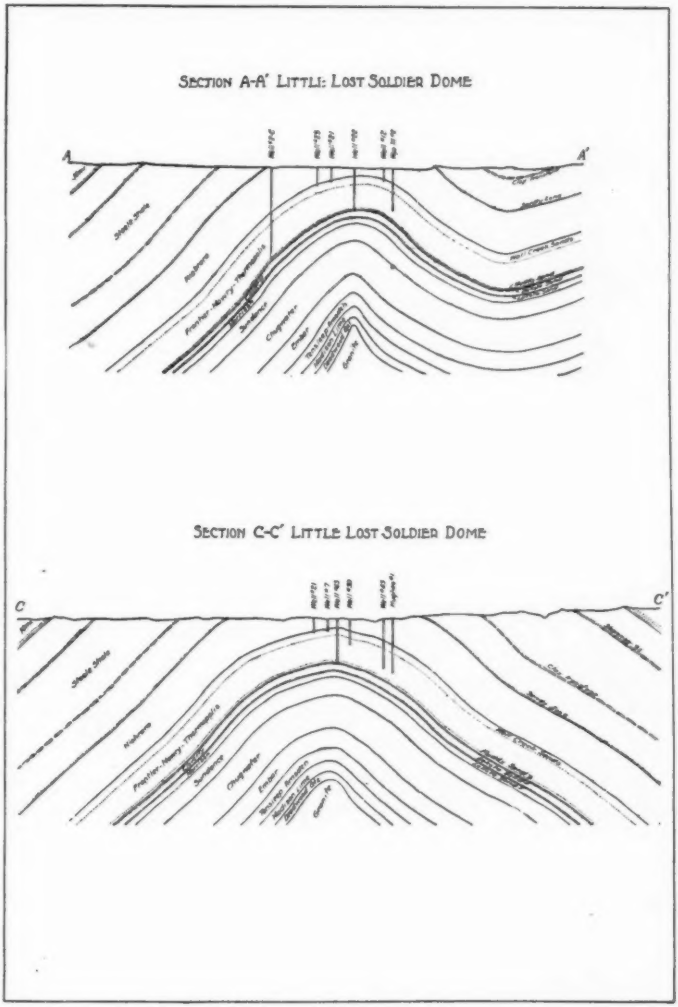
SECTION A-A' LITTLE LOST SOLDIER DOME
A
A'
SECTION C-C' LITTLE LOST SOLDIER DOME
C
C'

FIG. 3

ROCK FORMATIONS OF THE RAWLINS-LOST SOLDIER DISTRICT

System	Series	Group	Formation	Thickness in Feet	Characteristics
Quaternary		Recent		0–300	Sand dunes Lake beds Alluvium Terrace gravels
	Unconformity				
			Wasatch	1,800	Freshwater white ss. and sh. Local coal
Tertiary	*Unconformity* Eocene		Fort Union	6,000	Alternating beds yellowish-brown ss. and drab sh. Beds of rusty brown ss. in lower part. Local coal
	Unconformity				
?	?		Laramie	1,500	Alternating beds yellowish-brown ss. and dark sh. Local coal
Cretaceous	Upper Cretaceous	Montana	Lewis	1,000	Dark drab sh. including local ss. and beds of coal
			Mesaverde	1,500–2,000	Alternating beds ss. and drab sh. with beds of coal. Prominent beds white ss. at top and bottom
		Colorado	Steele	4,520	Dark sh. upper part sdy. grading upward into ss. Lower part slightly sdy. with irregular sand at base
			Niobrara	1,385	Dark gray sh. with several persistent concretionary claystone beds at top. Upper 400 ft. might have been included in Steele sh. Lower 300 ft. may be Carlile sh.
			Frontier	660	Upper part consists of from 3 to 7 sandstones with thinner beds of sh. Lower part dark gray sh. with occasional thin ss.
			Mowry	360	Dark fissile sh., weathering silver gray on exposed surfaces
			Thermopolis	75	Black sh. with sandy layers and one or more thin white sandstones
Cretaceous	Lower Cretaceous	Cloverly	Dakota	40	Uniform fine-grained white ss.
			Fuson	105	Dark gray sh. above varicolored sh. below, sometimes sandy
			Lakota	60	Massive conglomeratic ss.
	Local Unconformity				
Jurassic			Morrison	225	Gray and greenish sh. alternating with green sdy. sh. and white ss.
			Sundance	625	Fossiliferous ls. and gray sh. above. Buff ss. below
Triassic Permian			Chugwater	1,200	Bright red sh. and ss. several prominent beds of white ls.

ROCK FORMATIONS RAWLINS-LOST SOLDIER DISTRICT—*Continued*

System	Series	Group	Formation	Thickness in Feet	Characteristics
Permian			Embar	660	Pink and white ls. alternating with red limy shale. Gypsum
Pennsylvanian			Tensleep	450	Massive white ss. above. Thinner bedded ss. alternating with sh. below
Mississippian	*Unconformity*		Madison	350	Massive white ls.
Cambrian	*Unconformity*		Deadwood	400	Purple to pink quartzite
Archean					Pink granite

None of the lower prospective producing sands have been thoroughly tested in any of the fields in this district. Possible sources of production are in descending order, the Morrison, Sundance, Chugwater, Embar and Tensleep formations (Fig. 4).

CRETACEOUS SYSTEM

Cloverly formation.—Bowen[1] gives a short, and comprehensive description of the Cloverly formation: "an upper member of sandstone, a middle member of shale, and a lower member of conglomeratic sandstone."

The upper member of sandstone consists of 20–50 feet of white, rather fine- and uniform-grained sandstone. On weathered outcrops the sand becomes iron stained and often somewhat quartzitic. This sand is known as the Dakota in the Lost Soldier district, where it is the most prolific producer of both oil and gas. The Dakota sand is underlain by a dark gray, somewhat sandy shale, below which is a variegated sandy shale and at the base a sand known as the Lakota.

The Lakota is a very conglomeratic, massive, cross-bedded sandstone, 40–60 feet thick. The writer believes that there is a general unconformity at the base of the Lakota, and local unconformities higher up in the Cloverly, up to the base of the dark gray shale below the Dakota. Number 1 gas well of the Kasoming Oil Company on Mahoney dome was drilled to a depth of 2,525 feet, or 365

[1] C. F. Bowen, "Stratigraphy of the Hanna Basin, Wyoming," *U. S. Geol. Survey*, Prof. Paper 108, 1918.

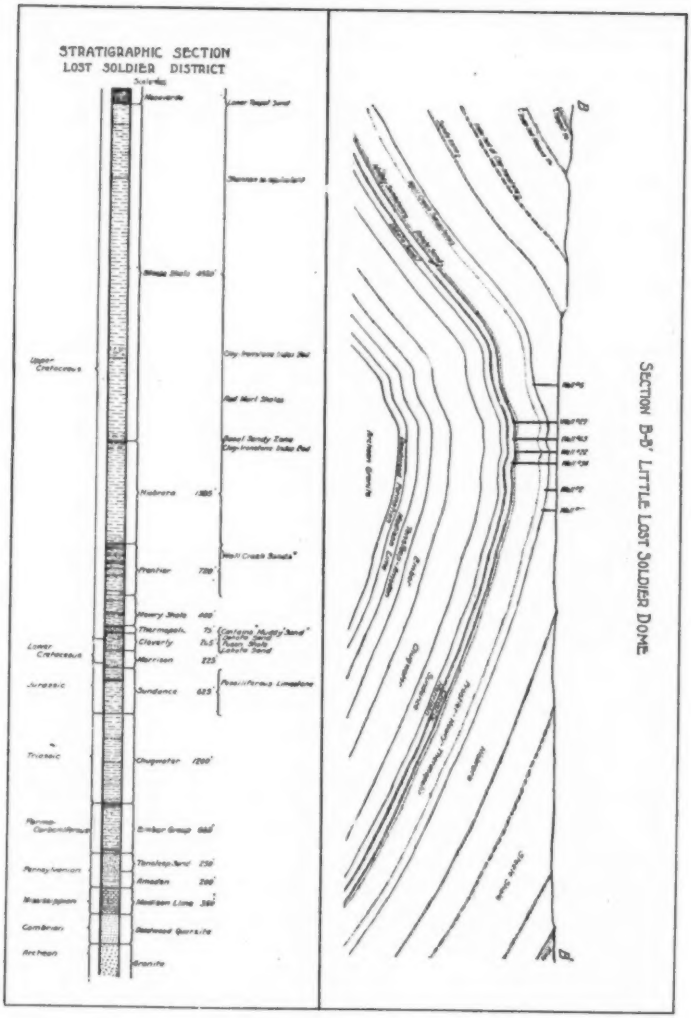
STRATIGRAPHIC SECTION
LOST SOLDIER DISTRICT
Scale
Upper Cretaceous
Lower Cretaceous
Jurassic
Triassic
Permo-Carboniferous
Pennsylvanian
Mississippian
Cambrian
Archean
Lower Teapot Sand
Thermopolis Shale
Cody Formation Hatch Rad
Red Marl Shales
Upper Sandy Zone
Gap Interbed Hatch Red
Hudsonia
Frontier
Wall Creek Sands
Mowry Shale
Thermopolis
Cloverly
Morrison
Sundance
Fossiliferous Limestone
Chugwater
Embar Group
Tensleep Sand
Amsden
Madison Lime
Bighead Quartzite
Granite
SECTION B-B' LITTLE LOST SOLDIER DOME

FIG. 4

feet below the top of the Dakota. The log indicates that all of the lower part of the Cloverly including the Lakota was missing.

Thermopolis shale.—The Thermopolis shale seems to vary greatly in character in various parts of the district. Typically it consists of soft dark shale with several thin beds of sandy shale and white sandstone. In the Little Lost Soldier field the lower 60 feet seem to consist of dark shaly sand which is oil-bearing. Directly north of the field at the nearest outcrop it consists of dark shaly sand, and includes a thin bed of coal which has been mined locally. In the west end of Mahoney dome there seems to be no sand at all in the Thermopolis shale, but in the east end the Ohio Oil Company reports a thin gas sand at approximately the top of the formation.

Mowry shale.—The Mowry shale is typically developed in the Lost Soldier district. It consists of approximately 360 feet of very hard, dark fissile shale intercalated with the softer beds of black shale and beds of bentonite. The Mowry weathers out as a silver-gray fissile shale, fragments of which are exccedingly hard. Fish scales are common. Probably the Mowry shale is the origin of most of the oil found in the Dakota sandstone. As the Thermopolis shale is thin and quite sandy, the oil originating in the Mowry migrates downward into the Dakota rather than upward through relatively impervious shales to the Wall Creek sands.

Frontier formation.—The upper 300 feet of the Frontier formation consist of three or more thick sandstones alternating with thinner beds of shale. The lower part consists of dark shale with thin irregular or lenticular beds of sandstone. The shallow sand production at the Little Lost Soldier dome is from the Frontier sands, and two gas wells on Sec. 34, Mahoney dome, got a small flow of gas from the lower member of the formation. In other parts of Mahoney dome, and in the Wertz and Ferris domes the Frontier sands are barren. The Ohio Oil Company got a good showing of gas (1 to 3 million cubic feet) in a Frontier sand at O'Brien Springs. This is encouraging as the showings in the Wall Creeks are often an index of larger production of the same kind in the Dakota.

Niobrara formation.—In the eastern part of the state and even in the Elk Mountain and Miller Hill districts the Niobrara shale is a distinct lithologic unit. In the Lost Soldier district, however,

the 1,385 feet of gray shale from the top of the upper Frontier sandstone to the top of a very persistent yellow concretionary claystone seem to be without a lithologic break of any kind. Near the middle of this bed of shale *Ostrea congesta* and *Inoceramus deformis* can occasionally be found though they are rare. Nearer the top crinoid remains are locally numerous. C. H. Hares says the crinoids are characteristic of the Niobrara in other localities. The division in the table is an arbitrary one, and to conform with stratigraphy of other districts the lower 300 feet should probably be called Carlile shale and the upper 400 feet included in the Steele shale.

Steele shale.—The Steele shale consists of 4,520 feet of dark shale with an irregular sandstone at the base. This lower sandstone is probably the source of the oil in the G. P. dome. It also forms the rimrock around the Mahoney and Little Lost Soldier domes. It is a valuable horizon marker both when exposed at the surface and when encountered in wells. The upper 1,200 feet of the formation is sandy, grading into the Mesaverde. The upper limit is placed at the base of a persistent sugary white massive sandstone, known locally as the Lower Teapot. Under this subdivision the Steele shale contains some very thick and persistent sandstone beds in its upper part.

STRUCTURE

The Lost Soldier and Miller Hill districts, taken together, comprise an extensive upfold, extending from the Sierra Madre Mountains at right angles up to the Sweetwater uplift. The producing structures are parallel to the Sweetwater uplift and the stresses producing them came from that direction. The Wertz, Mahoney, and Ferris domes are structural high points on one anticlinal axis running parallel to the Sweetwater uplift. The Little Lost Soldier dome is a short domelike upfold almost parallel to the Wertz dome and lying on its basinward side. The Bunker Hill dome is another short domelike fold which lies on the mountainward side of the Wertz dome. At Mahoney dome the anticlinal axis seems to divide, and a secondary axis starting at the crest passes through the southwest corner of the dome and swings around through the O'Brien Springs anticline into the Hanna basin. No other structural high points

on this axis have been found owing to the surface covering of wind-blown sand, but the drilling now in progress may prove that some do exist.

LITTLE LOST SOLDIER DOME

The Little Lost Soldier dome is a sharp upfold characterized by steeply dipping flanks and considerable dip faulting. The axis runs approximately north 30° west. On the west flank the dips increase rapidly from zero at the crest to 45° and then gradually flatten out. On the east the dips start at zero at the crest and increase to about 35° in the syncline which separates the Lost Soldier dome from the Wertz dome. The plunging of the axis to the north and south is not so steep, not exceeding 25°. The closure of the Lost Soldier dome is about 3,100 feet.

The Upper Frontier sand is the shallowest producing sand, being reached on the apex of the dome at 239 feet. The oil pool in this sand covers about 160 acres. The other sands of the Frontier, even including some of the lower lenticular sands also produce some oil near the crest of the dome.

The next producing horizon is in the Mowry formation about 300 feet above the Dakota sand. Twelve wells have been drilled into or through this horizon and all of them have encountered oil. The average well has around 200 barrels initial production, though at least two wells showed much greater production—500 and 700 barrels.

In nearly all cases this production has been cased off in order to reach the Dakota sand, about 300 feet below. Drillers usually report it as black sand but the writer has repeatedly examined the drillings and has been unable to find any sand in them. The Bair Oil Company is now drilling a well on the west flank of the dome which has probably passed through the Mowry without a showing of oil. The oil pool in the Mowry covers about 680 acres at the crest of the dome.

The next and most important producing sand is the Dakota, together with the shaly sand of the Thermopolis, or Muddy sand just above it. The Muddy sand is dark colored and the Dakota is a fine-grained white sand. Nine wells have been completed to the Dakota, six of them in 1922. The initial production ranged

from 300 to 4,000 barrels. Two of the wells, thought to be producing from fault zones, came in at 3,000 to 4,000 barrels. The logs do not indicate that the Dakota has been reached in these wells. The oil from these two wells is hot (120°F) which may partly account for the large flow.

The limit of the pool in the Dakota sand has not been proved. It seems possible that the area will be as great as 1,500 acres. The actually proved area from wells now completed is about 500 acres. The potential production of the field at present is about 12,000 barrels daily. The actual production is 4,000 to 5,000 barrels.

WERTZ DOME

The Wertz dome is 2½ miles east of the Little Lost Soldier dome and separated from it by a deep syncline. The sands are much deeper, the Dakota being reached at 3,400 feet in contrast to 1,415 feet on the Little Lost Soldier dome. The Producers and Refiners Corporation have completed one well which is the gasser previously mentioned in this paper. The outcropping formation is soft Steele shale covered with alluvium, and little information is therefore available as to the structure except as outlined by the Mesaverde escarpment. It is interesting to note that the Mowry shale contains oil in the Wertz dome and that the gas well is producing gas from the Dakota through the inner casing, and some oil from the Mowry between casings.

MAHONEY DOME

Seven gas wells have been completed on the Mahoney dome, all producing from the Dakota sand. The Kasoming Oil Company has recently completed a well with a showing of oil in the Dakota sand indicating that there is some oil below the gas in the same sand. On the south flank three wells have been drilled which were failures. They may be located too far down the flank for oil but it looks more probable that the amount of oil under the gas is not great, and that the Mahoney dome field will never produce a great amount of oil.

Much of Mahoney dome is concealed beneath sand dunes so that the structure must be worked out in part from well logs. On

the south and west the dips do not exceed 8° to 10°; on the north they are considerably steeper. The east end is covered, but the last well drilled by the Ohio indicates by its depth that the field extends farther east than was formerly supposed and that it may connect with the Ferris gas field.

G. P. DOME

The General Petroleum Corporation drilled a number of holes south and east of the Ferris dome field and succeeded in bringing in two or three wells from what appears to be the sand at the base of the Steele shale. The wells were deep—over 3,000 feet—and when put to a test did not hold up well. The company has stopped drilling in this part of the field, though they are still pumping the wells completed. The Sand Hills Company in the same locality also got a little oil in several wells and are still drilling at least one well with the hope of getting oil in lower sands.

OIL AND GAS

SURFACE INDICATIONS OF OIL

So far as known to the writer, there are no seeps or oil springs anywhere in the Lost Soldier district. The only indication of the possible presence of oil was the geological structure.

QUALITY OF OIL

The Dakota sand oil is a paraffin base oil, gravity 32°–33° Baume, with an exceptionally high percentage of paraffin. The Frontier sand oil has an average gravity of 31° and contains a little less paraffin than does the Dakota oil.

The oil at Mahoney dome is of higher gravity, 38° Baume, but otherwise appears to be similar to the oil from the Dakota at Little Lost Soldier. The Ferris dome oil is very high in gasoline with a gravity of 39.3° Baume.

DISCUSSION

W. E. WRATHER: I am very much interested by Mr. Krampert's statement that the oil found in known fault planes in the Little Lost Soldier field has a temperature of 120° F. while the normal temperature of oil in nearby wells is around 70°. Abnormal oil temperatures are usually considered to presage

the early influx of water, especially where the oil has an asphaltic base. In fact, about the only recorded instance of abnormal temperatures in paraffin-base oils is that in the Ranger district.

Here apparently is a new clue to the cause of unusual temperature of oil, which certainly cannot be relied upon in the majority of cases, but which nevertheless may offer an explanation to this phenomenon in local instances. It is greatly to be hoped that geologists will interest themselves generally in the subject of oil and water temperatures, and thus assist in arriving at logical conclusions as to the causes.

G. B. MORGAN: If it is true that the well in Sec. 26 on the north side of Mahoney dome which is producing oil is on the same contour as a water well on the south side, yet the north flank is the flank of high water pressure and the south flank the one of large drainage area, what explanation do you offer for this phenomenon?

E. W. KRAMPERT: These are approximately the facts, but I have no explanation.

OIL AND GAS POSSIBILITIES OF EASTERN ALBERTA

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INTRODUCTION

The almost negligible production of oil in a country possessing the population and market of Canada is an economic situation ideal for profitable exploitation of oil and gas resources, and is a strong incentive for thorough exploration in search of these products. The present supply of petroleum products for the prairie provinces of Alberta and Saskatchewan comes from Montana and Wyoming. Naturally, due to transportation charges, the prices are high and the market is favorable to the producer. Furthermore, the Dominion Government now pays a bounty of 60 cents per barrel on oil produced in Canada. These facts, together with the strong probability that a comparatively high duty will be placed upon imported crude oil as soon as Canadian production warrants, all indicate a strong strategic position for the producer of petroleum, provided the oil can be found.

It is true that oil has been found in what promises to be commercial quantity at Norman in the far north, but inasmuch as this discovery is 60 miles farther north than the Klondike gold field, and is farther from the Canadian centers of population than the Gulf of Mexico, it can only be of interest as an indication of possible production in Devonian and post-Devonian strata at points nearer to civilization. The Norman district can never compete with any fields which may be found in southern Canada, nor with imported oil from adjacent portions of the United States.

With the exception of a narrow strip of territory along the southwestern boundary, which is occupied by the Rocky Mountains, the entire province of Alberta possesses, at least in a general way, some of the prerequisite conditions for oil and gas fields. The prospective oil and gas territory is comprised in two topographic prov-

inces, (1) the foothills belt, which is contiguous to the mountains on the northeast, and (2) farther northeast, the prairie plains province. The foothills province is now yielding some small oil production, but as this province is not large and as it has been treated already in a paper by Wesley Purdy,[1] it will not be considered further. The prairie plains province, particularly the better known southeastern portion, will be considered in this paper.

LOCATION

An area comprising over 200,000 square miles in Alberta and adjacent portions of Saskatchewan is underlain by Cretaceous and Devonian strata and has, so far as stratigraphy is concerned, oil and gas possibilities. On account of structural and economic considerations chief attention in the field was given to the region between Edmonton, Alberta, and Battleford, Saskatchewan, on the north, and the Sweetgrass Hills of Montana, near the Canadian boundary on the south. This area is roughly 350 miles long from north to south, by 200 miles wide from east to west (Fig. 1).

STRATIGRAPHY

Unfortunately, Pleistocene deposits mask a considerable portion of this region, but where they are absent, Tertiary and Cretaceous beds predominate at the surface with the underlying Devonian and Devono-Carboniferous strata exposed in the deeper valleys toward the north. Since the Tertiary rocks occupy the synclinal basins, and the higher formations of the Cretaceous system outcrop in the areas of more favorable structure, the Tertiary system is not the handicap to exploration which it might be otherwise.

Borings, outcrops, and seeps indicate the petroliferous character of the lower portion of the Upper Cretaceous, the Lower Cretaceous, and the Devonian strata. It may be concluded, therefore, that the area lies within a petroliferous province.

The following table of formations is based on Canadian Geological Survey reports by D. B. Dowling, S. E. Slipper, and F. H. McLearn[2] in which descriptive details may be found.

[1] "A Summary of the Canadian Foothills Belt," *Am. Assn. Petroleum Geol.*, Bull., Vol. IV, 1920.

[2] *Memoir 116, Geol. Surv., Canada*, 1919.

TABLE OF FORMATIONS

	Southern Alberta		Central Alberta
Tertiary.....	Paskapoo (Porcupine Hills beds) Willow Creek beds		
Cretaceous.....	Edmonton (St. Mary River beds)		Edmonton formation
	Bearpaw formation		Bearpaw formation
	Belly River series	Pale beds	Pale beds
		Foremost beds	Variegated beds Birch Lake sandstone Grizzly Bear formation Ribstone Creek formation
		Pakowki shale	Lea Park formation
		Milk River (Eagle) sandstone	Thin or absent
	Colorado formation		Colorado formation
	Blairmore (Dakota) formation		Blairmore (Dakota) formation
	Kootenai formation		Kootenai formation
Carboniferous and Devonian..	Paleozoic limestone		Paleozoic limestone

STRUCTURE

Major structure.—The dominant structural features of southern Alberta are, from west to east, the Rocky Mountains, the strongly folded Foothills belt, the broad Alberta syncline, and the northern extension of the Sweetgrass arch of Montana, which, in Alberta, north of the Bow Island gas field ceases to be an arch and passes into a monoclinal flexure known as the Central Plains terrace.

The Alberta syncline is a very large structural basin the axis of which passes approximately through Cochrane. The trend of the axis is a little west of north, roughly parallel to the Rocky Mountain front. From this synclinal axis the strata rise northeastward at a low angle for a distance of about 250 miles, until, along a sinuous line of monoclinal flexure the dip increases for a few miles, then flattens to practically horizontal. The east limb of the Alberta syncline is thus a homocline of 250 miles maximum width, and the regional dip is generally at a low angle south 65° west. Minor

folds on this homocline have prospective value, but so far none of importance has been discovered. The synclinal area is inherently less favorable than the anticlinal and terrace structure to the east.

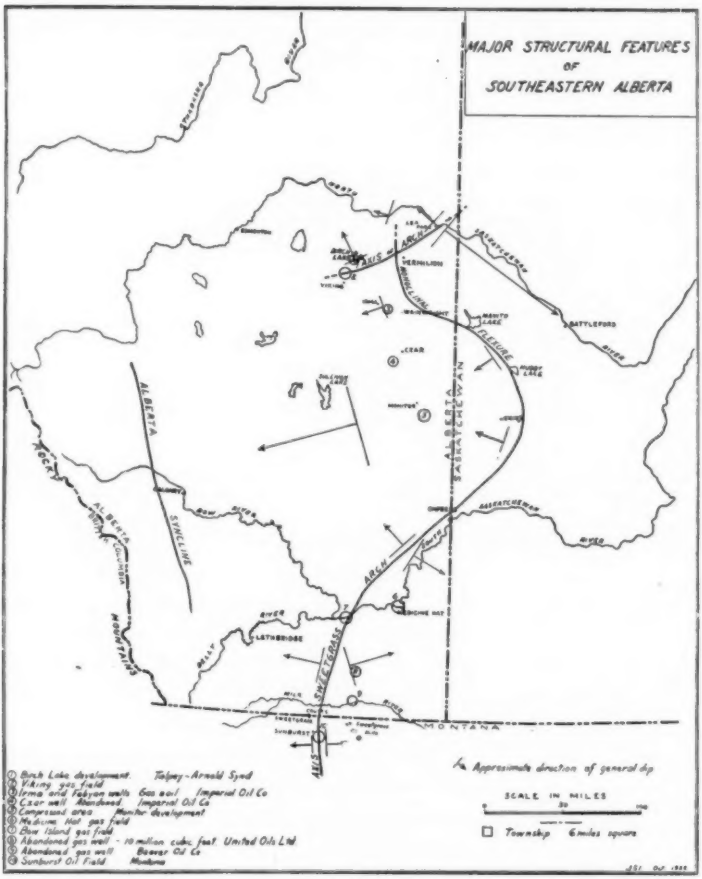

FIG. 1

The area on and adjacent to the northward extension of the Sweetgrass arch appears to offer the best prospects for oil and gas in southwestern Canada. The axis of this arch enters Canada at a

point about seven miles west of Coutts, Alberta, according to a structure map prepared by the writer. The anticlinal axis extends northward 65 miles to the vicinity of the Bow Island gas field on South Saskatchewan River, whence it swings northeastward[1] to the vicinity of Empress, Alberta. Not far beyond Empress the geanticline passes into a monoclinal flexure or terrace, the anticlinal axis continuing as a line of monoclinal flexure. From Empress this axis continues northeastward toward Kindersley and Ermine, Saskatchewan. It then bends to the northwest passing near Muddy Lake and Manito Lake, Saskatchewan, back into Alberta north of Wainwright, crossing the Canadian National Railway between Birch Lake and the town of Vermilion, Alberta. The general position of the anticlinal and monoclinal axes was determined from borings and from field observations along Saskatchewan River and Birch Lake by the Canadian Geological Survey and from field observations by the writer near Birch Lake, along Battle River near Irma, Hawkins and Fabyan, along South Saskatchewan River in the Bow Island gas field, along Milk River just north of the United States boundary, and in Toole County, Montana.

Transverse to the monoclinal flexure a gentle cross-fold is in evidence near Viking, Birch Lake, and Vermilion. Sections by J. A. Allan[2] of the Canadian Geological Survey drawn in a southeast-northwest direction, one through Birch Lake, Alberta, and one through Lea Park, Saskatchewan, indicate high points at those places. Thus "the sandstone on the shore of Birch Lake has an elevation of 2,140 feet, whereas the same sandstone on the North Saskatchewan near Pakan has an approximate elevation of 1,850 feet, indicating a depression of 290 feet in somewhat over 50 miles",[3] which represents a pitch of approximately six feet per mile on the axis of the monoclinal flexure. The culminations near Birch Lake and Lea Park therefore determine a northeast-southwest anticlinal axis transverse to the major monoclinal axis. Further evidence of an anticlinal cross-fold in this vicinity was disclosed by a subsur-

[1] *Mem. 116* (Map, Pub. No. 1779), *Geol. Surv., Canada*, 1919.

[2] *Summary Report* (1917), *Part C, Geol. Surv., Canada*, 1918.

[3] S. E. Slipper, *Summary Report* (1917), *Part C, Geol. Surv., Canada*, 1918.

face structure map prepared from the seven available logs of the nine Viking gas wells.

It is believed that the general area adjacent to the axis of the Sweetgrass arch, to the axis of the monoclinal flexure (Central Plains terrace) and to the Viking–Lea Park transverse anticlinal axis is the most favorable locality to prospect for minor structures which may contain oil and gas.

DEVELOPMENT WITH RELATION TO STRUCTURE

In the region of the Sweetgrass arch and Central Plains terrace of Alberta, outside of the Viking and Bow Island gas fields, some eighteen wells have been drilled and from five to ten are now drilling in search of oil and gas. Considering the size of the area to be prospected—some 50,000 square miles—comparatively little drilling has been done. Furthermore, as might be expected, most of the drilling until recently has been without geological guidance.

Bow Island gas field.—Twenty-three gas wells were drilled in this field, which lies along South Saskatchewan River about 60 miles north of the United States boundary, near the town of Bow Island. In 1914 sixteen wells were capable of producing 75,000,000 cubic feet of gas per day. Calgary, Lethbridge, and intermediate towns were supplied with gas. The average capacity of the wells was from 5,000,000 to 10,000,000 cubic feet, although one well had a flow of 29,000,000 cubic feet. The rock pressure in the field was 800 pounds maximum and 750 pounds average. The gas is dry, yielding but one-tenth pint of gasoline per 1,000 cubic feet. The average depth of wells in the river bottom is 1,980 feet. The average commercial life of a well was five years.

The gas sand is a member in the lower part of the Colorado shale about 400 feet above the base, and hence corresponds in position to the Muddy sand of Wyoming. The sand is tight, compact, hard, and fine, and occurs in two beds, each about 10 feet thick and separated by 34 feet of shale. Each bed is composed of "broken" sand, poorly constituted to serve as a reservoir. Never more than 5 feet of good clear sand was found. Both the gas sands and the break between them thin out toward the west and south, so that in those directions the productive area is limited by pinching out of the sand.

Water limits the field on the east and north. The dip is 14 feet per mile to the north and 7 feet per mile to the east, as determined from well records.

As seen in the outcrops along the river bluffs, the dip is 40 feet per mile to the west, just west of the westernmost gas well. Throughout the field east of this point the strata appear flat as determined by the hand level. In east-west cross-section the structure approximates a terrace, which subsurface data show to be slightly anticlinal in the gas sands. In north-south section the dip is northward 14 feet per mile, the dip being largely, if not entirely, due to the pitch of the Sweetgrass arch. So far as known there is no reverse dip to the south. The tightening or thinning out of the sand to the south is apparently sufficient to prevent the escape of the gas in that direction. So far as known no holes have been drilled far below the gas sand.

Viking gas field.—The Viking gas field is situated four miles north of Viking, Alberta, a small station on the Grand Trunk Pacific Railway, 80 miles southeast of Edmonton. In the spring of 1921, nine gas wells had been completed, having an average capacity of 5,000,000 cubic feet per day. The wells are shut in and have never been operated.

The gas is from sand members not far above the base of the Colorado shales and is approximately the same as the Bow Island gas sand. As at Bow Island, two sand beds occur but here they are separated by 120 feet of shale. The upper sand, 35 feet in average thickness, is the main gas producer, and it is reached at depths ranging from 2,146 feet to 2,200 feet. Drilling has never been carried more than 200 feet below the gas sands. In this 200 feet gas, salt water, and small amounts of heavy asphaltic oil have been encountered.

Records of seven of the Viking gas wells reveal an anticlinal fold having an axis transverse to the major monoclinal flexure and approximately coincident with the structural high through the south side of Birch Lake and Lea Park. The dips on the southeast flank of this fold, as determined by well records, vary from 14 to 40 feet per mile. A considerable area northeast of the Viking gas field in the general vicinity of the intersection of the monoclinal

flexure and the Viking–Birch Lake–Lea Park axis is especially favorable for oil and gas accumulation.

Irma-Fabyan District.—Visual evidence of the major monoclinal flexure is to be had in this vicinity along Battle River and the Grand Trunk Pacific tracks. Near the Gratton Creek Oil Company's gas well south of Hawkins switch the dip on the Birch Lake sandstone is definitely westward and the strata continue to rise toward the northeast to a point just east of Fabyan. From there onward to the northeast the beds are practically flat.

In 1914 and 1915 the Gratton Creek Oil Company drilled a well in Sec. 4, T. 45 N., R. 8 W., on the bank of Battle River. This well started just below the Birch Lake sandstone, entered the Colorado formation at about 800 feet and finished in the same formation at 1,620 feet. The log reports gas at 192 feet, water at 270 feet, water and oil at 300 feet, oil at 1,215 and 1,582 feet, and 500,000 cubic feet of gas at 1,620, at which depth gray shale is reported in the log. The gauge stood at 670 pounds. The Gratton Creek well is located on the steep slope of the major monoclinal flexure.

The Imperial Oil Company is drilling a well in Sec. 18, T. 45 N., R. 7 W., about one mile west of Fabyan. On June 19, 1922, report of this well showed 12,000,000 cubic feet of gas at 1,870 feet shut off; hard shell below, on which casing was set; heavy black oil below this shell; the gas breaking through and blowing oil over the derrick; more gas at 1,910; well cleaned out and drilled to 1,925; three barrels of light oil brought up in the bailer from between 1,962 and 2,000; drilling suspended and information withheld. The gas sand at 1,870 and the oil sand around 1,962 probably are the equivalents of the Viking gas sands in the lower part of the Colorado formation. This well is situated not far from the axis of the monoclinal flexure, probably a little west of the flattening.

Czar District.—There is some evidence of folding in the southwest corner of T. 39 N., R. 7 W., but the dips of 18° to 40° in Sec. 9, T. 39 N., R. 7 W. are almost certainly not due to folding and are not indicative of the structure. The Imperial Oil Company drilled a hole to a depth of 3,500 feet on Sec. 17, T. 39 N., R. 7 W., without favorable results. The chief significance of this test is that the lower part of this hole was in limestone, probably of Paleozoic age,

and the limestone was cavernous. It is thus demonstrated that the Paleozoic group can be reached by a hole of reasonable depth even in a location many miles down the dip from the axis of the major uplift. The cavernous nature of the limestone or dolomite is also suggestive.

The Czar District is situated in the compressed area, thought by the Canadian Survey to be the result of the abrupt bend in the major uplift lying to the eastward.

Monitor District.—Three or more wells have been drilled or are in process of drilling near Monitor, Alberta. This development is in the compressed area and is not favorably situated with respect to the major anticlinal and monoclinal structure which lies 60 miles to the east. Attention has probably been drawn to this district by the dips of 20° to 70° in the Belly River beds exposed in the Mud Buttes south of Monitor. These dips are almost certainly not the result of folding, but may have been produced by the action of glaciers. It is not unlikely, however, that gentle folds will be found in this compressed area, and, if found, they should have prospective value.

Etzikom Coulee.—The well drilled to a depth of 3,715 feet in Etzikom Coulee, Sec. 31, T. 5 N., R. 10 W., a few miles southeast of Foremost, Alberta, by the United Oil Company, Ltd., is of considerable interest because of the rather complete record it furnishes. This well started in the Belly River formation, 685 feet above the bottom of its basal member, the Milk River (Eagle) sandstone. About 500 barrels of fresh water per day now flow from the Eagle sandstone. The Colorado shale, 1,776 feet thick, was penetrated from 685 to 2,461. At 2,250 feet salt water flowing 7,000 barrels per day was encountered. At 2,015 feet a flow of 10,000,000 cubic feet of dry gas from five feet of sand was obtained. This sand is 440 feet above the Dakota sand and is the same as the Bow Island gas sand. The rock pressure was 800 pounds. The Dakota and Kootenai formations were penetrated from 2,461 to 3,210 feet. At the base of the Kootenai a sandstone series 220 feet thick was encountered, 65 feet of which near the top was saturated with plastic, asphaltic material similar to the McMurray tar sands. The stratigraphic position is also the same. Below the Kootenai were

410 feet of limestone and 85 feet of greenish gray shale to the bottom at 3,715. These are referred without differentiation to the Paleozoic.

The United Oil Company's well is situated very close to the major anticlinal axis of the Sweetgrass arch, but, though some evidence of local folding was observed, the writer's examination was not sufficient to indicate the presence or absence of a closed local structure. The chief significance of this well is the petroliferous character of the strata which is demonstrated, and the finding of the pre-Kootenai limestone at a depth of 3,210 feet.

Milk River.—A well drilled by the Beaver Oil Company in Sec. 24, T. 2 N., R. 11 W., about 12 miles north of the United States boundary gave practically the same log as that of the United Oil Company's well except that it is 300 feet higher on the Sweetgrass arch. The big gas was found at 1,700 feet and an oil sand was entered at 2,690 feet with a big flow of salt water in the hole. Oil was noted by the writer on the water escaping from this hole.

For the records of 52 wells drilled in the provinces of Alberta, Saskatchewan and Manitoba, reference is made to reports of the Geological Survey of Canada.[1]

Medicine Hat.—A gas pool of commercial value near Medicine Hat, Alberta, has produced for a number of years and is now declining. The gas comes from the Milk River (Eagle) sandstone and is situated on the northeast flank of the Sweetgrass arch. The local structure has not been studied by the writer.

OIL AND GAS POSSIBILITIES

It is evident from a consideration of the foregoing data that the lower part of the Upper Cretaceous, the Lower Cretaceous and the upper portion of the pre-Cretaceous strata of western Canada contain considerable amounts of hydrocarbons. Sandstone members capable of serving as oil and gas reservoirs are abundant and the rocks are water-saturated, indicating that upfolds should be productive. The most serious lack among the requisites for oil and gas accumulation, so far as southeastern Alberta is concerned, is the gentleness of the folding and the consequent scarcity or absence

[1] *Mem. 116, Geol. Surv., Canada,* 1919.

of well-defined domes and anticlines. By no means sufficient prospecting has been done, however, to warrant the conclusion that adequate structures do not exist, and as has been noted, considerable gas production has already been obtained from terrace structures, lenticular sands, and possibly from anticlines or domes having flanks inclined at angles of less than one-half degree.

The finding of oil in commercial quantities on the adjacent higher portion of the Sweetgrass arch in Montana demonstrates that dips of less than one degree are sufficient to localize petroleum in the Mesozoic strata of the Rocky Mountain region. Hence, it appears that folds of the Mid-Continent type should be searched for and explored by drilling.

The haphazard exploration which has thus far been carried on in Western Canada indicates that the Paleozoic system lies within reach of the drill, but that these rocks have been penetrated in but two or three places. Very gentle folds might be found to be productive in these older rocks as is the case in many other portions of North America. It is also possible that very gentle folds in the Cretaceous may be intensified in the Paleozoic strata, as is so frequently the case elsewhere, The possibility of increase of dip with depth is, however, considerably greater as we proceed northwestward since there is practically no discordance between the Cretaceous and the Paleozoic strata in southeastern Alberta. Discordance increases, however, toward the northwest.

Extreme flatness of dip in the three commercial gas pools, Bow Island, Medicine Hat, and Viking, gives very limited capacity to the respective sand reservoirs. As enough gas is present in each case to fill the structure completely, there is no room for oil below the gas. This situation may explain the prevalence of gas and scarcity of oil in this region.

SUMMARY

1. The petroliferous character of strata of Upper Cretaceous, Lower Cretaceous, and Devono-Carboniferous age in western Canada has been demonstrated.

2. A major structure of great horizontal and limited vertical development extends from the Sweetgrass arch in Toole County, Montana, in a sinuous line through eastern Alberta and western

Saskatchewan toward Athabasca River in northern Alberta. The structure is anticlinal in the south, monoclinal in the central and northern portions. This major structure, and minor structures on or near it, are the most favorable localities in which to prospect for oil and gas.

3. All of the Upper Cretaceous, Lower Cretaceous, and the upper part of the Devono-Carboniferous strata can be reached by present-day methods of drilling.

4. Many rocks capable of serving as oil and gas reservoirs occur in the geologic section.

5. The most serious unfavorable condition in the region is the lack of well-defined anticlines and domes. However, recent development on the Montana portion of the Sweetgrass arch indicates that commercial oil pools may accumulate in Mesozoic strata of the Rocky Mountain region where the inclination of the beds is less than one degree. Exploration has barely begun. As it progresses, with the major structure for guidance, better defined minor structures may be found, especially toward the north and northwest where gentle folds at the surface are more likely to be intensified at depth.

6. Deeper drilling will test the Paleozoic strata which characteristically yield petroleum and gas on very gentle folds, where they are petroliferous.

COMPARATIVE STRATIGRAPHY IN MONTANA

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INTRODUCTION

In the Rocky Mountain Province, stratigraphy is perhaps the most important consideration in the prospecting and developing of a new oil field. Without an adequate source, or reservoir rock, an anticline or dome will be barren. Hence a study of the character and succession of strata, to a greater or less extent, should precede a study of structure in any area.

In Montana petroleum has been found in commercial quantities in the lower part of the Upper Cretaceous, in the Kootenai, Ellis, Amsden, and Quadrant formations, and important shows of oil have been obtained in the Eagle, Cloverly, Tensleep, and Madison. In this paper the authors have attempted to set forth the important features of the series of strata between the top of the Eagle sandstone and the top of the Madison limestone, which comprise all the formations enumerated above. They have also pointed out some correlations which may assist in clarifying the stratigraphy of the state.

Stratigraphic changes are most notable and pronounced in the Upper Cretaceous sediments from east to west, while in the older sedimentary rocks, the changes are greater from south to north (Fig. 2). The Lower Cretaceous has a greater thickness in the northern part of the state though the Morrison is not differentiated north of Great Falls. The Jurassic is fairly constant in thickness over the state, though it is somewhat thinner to the north. The Triassic represented by the Chugwater in the south is absent in sections exposed north of Yellowstone River. The Permian, though not differentiated in sections east of the main mountain range, is in all probability very thin if present at all. The Pennsylvanian varies greatly in thickness and character in the southern half of the state, and north of Missouri River it is known to be

absent over large areas. Even where unconformities are known to exist, the foregoing systems of rock strata present no marked discordance in dip in any of the localities discussed in this paper.

The authors have selected six areas for discussion, (Fig. 1) and stratigraphic sections have been chosen (Fig. 2) which depict the major changes in stratigraphy in the portion of the state most interesting to the oil geologist. In the table of formations (Fig. 3) are shown the various formation names, together with the writers' interpretation of their correlation. This table gives also the thickness of

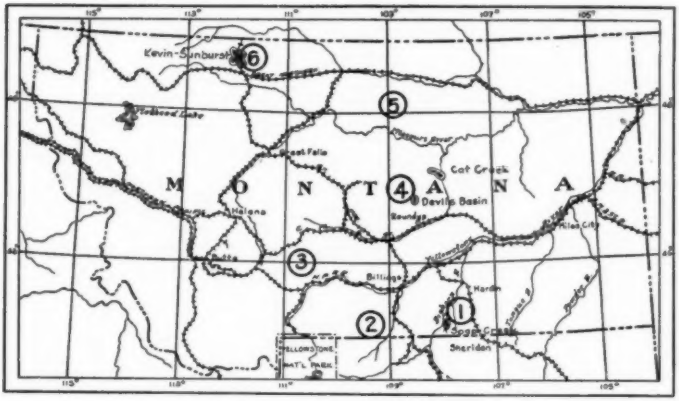

FIG. 1

the formations in the various areas in which the sections are located. In some cases where one figure is given, it indicates an average thickness. Where the formations are variable in thickness, a maximum and minimum are given. The small letters(*o*) and (*g*) are used to indicate shows of oil and gas. Capital letters similarly used indicate commercial production.

In the following discussion each formation is described as it occurs over the state, beginning with the higher and proceeding to the lower. In the text and on the plate of sections (Fig. 2), credit is given to the men who measured the sections, though they have been checked in most cases by the writers.

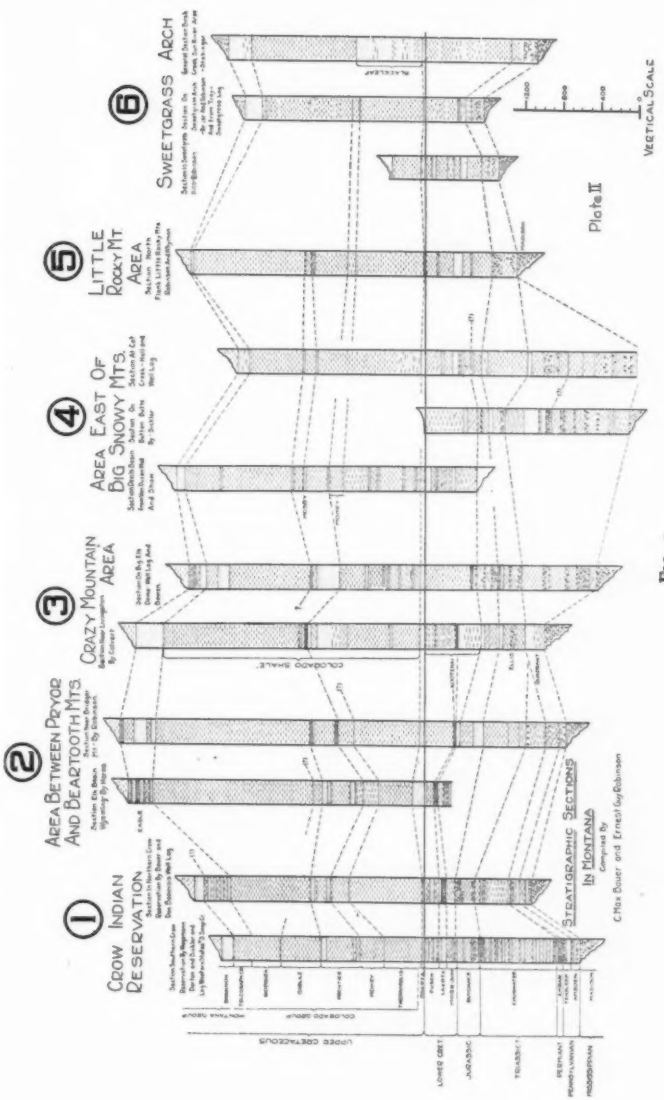

Plate II

FIG. 2

"EXPLANATION"
O = Oil Production
G = Gas Production
+ = Show Of Oil
S = Show Of Gas
Figures Indicate Thickness in Feet

TABLE OF GEOLOGIC FORMATIONS IN MONTANA.

GIVING THICKNESS AND CORRELATIONS.

By

Bauer and Robinson.

PERIOD		NORTHERN WYOMING	LOCALITY "1 SOUTHERN CROW INDIAN RESERVATION	LOCALITY "2 WEST OF BRYDR MOUNTAINS	LOCALITY "3 CRAZY MOUNTAINS	SOUTH SIDE JUDITH BASIN	LOCALITY "4 EAST OF BIG SNOWY MTS.	LOCALITY "5 LITTLE ROCKY MOUNTAINS.	LOCALITY "6 SWEETGRASS ARCH	UPPER SUN RIVER
UPPER CRET.	MONTANA GROUP	Shannon (170)	Shannon (125)	Eagle + (368)	Eagle ; (290)	Eagle (183)	Eagle (115)	Virgelle + (20)	Virgelle (382)	Virgelle + (380)
		Shale (750)	Sandy Shale (300)	(Shale (1636)	shale (1440)	shale (1105)	shale (1185)	shale (1233)	shale (945)	shale (1100)
		Niobrara (850)	Niobrara (400)	Frontier + cg. at base (287)			Mosby ; (5)	Mosby (?) (6)		
	COLORADO GROUP	Carlile (200)	Carlile (400)	Colorado Shale (2162)	cg. (8+) 2688	Big Elk (290) 2532	Mowry (215 2235	shale (337) 2366	Mowry (80) 1725	Mowry (80) 1800
		Frontier (300)	Frontier (400)	Mowry (167)				Mowry (80)		
		Mowry + (175)	Mowry (250)	Thermopolis (692)				shale (730)	shale with thin SS. (700)	Blackleaf (700)
		Thermopolis (350)	Thermopolis (800)				shale (850)			
	HIATUS?	Dakota ? (100)	Dakota + (20)	Dakota + (55)	Dakota + (65)	Dakota (50)	Cat Creek + (55)	Dakota (4)	Dakota + (20-30)	Dakota (30)
LOWER CRET. (COMANCHEAN)		Lower Cloverly (150) Morrison (200-500)	Fuson (200) Lakota (100) Morrison (250)	Fuson (313) Lakota (10) Morrison (294)	Kootenai + (585) Morrison (185)	Kootenai + (560) Morrison (220)	Kootenai + (535) Morrison (127)	Kootenai (701) (not distinguished)	Kootenai ? (430-500)	Kootenai (890-920)
JURASSIC	UNCONFORMITY	Sundance + (200-450)	Sundance + (425)	Sundance (448)	Ellis (277)	Ellis (250)	Ellis (158)	Ellis (254)	Ellis ? (180-210)	Ellis (240-310)
TRIASSIC (?)	UNCONFORMITY	Chugwater + (800)	Chugwater (600-800)	Chugwater (200-400)						
PERMIAN (?)	UNCONFORMITY	Embar + (350)	Embar (?) (35)	Embar (0-100)	(absent)			(absent)		
PENNSYLVANIAN		Tensleep + (150-200)	Tensleep + (50-75)	Tensleep + (150)	Quadrant (200-750)	Quadrant (810)	Quadrant + (1310)			
	UNCONFORMITY									
MISSISSIPPIAN		Amsden (100-350)	Amsden + (150-350)	Amsden (73)						
	UNCONFORMITY	Madison	Madison +	Madison	Madison	Madison	Madison	UNCONFORMITY Madison	Madison	Madison

FIG. 3

UPPER CRETACEOUS

Eagle Sandstone.—The type section of the Eagle sandstone[1] was measured on Eagle Creek, which flows into the Missouri River from the northeast in Chouteau County, Montana. In the type locality the Eagle is a marine and brackish water formation and is composed of three members; massive, almost white sandstones, above and below, with a shale member between. In northern Montana the shale and upper sandstone members are locally absent or are not recognizable. This has resulted in naming the lower member, the Virgelle sandstone,[2] from the excellent exposures of the bed at the town of Virgelle on Missouri River, below Fort Benton. In the region under discussion, the Eagle sandstone is usually referred to as the basal formation of the Montana group. There is some doubt as to the correctness of this reference.

On the south boundary of the Crow Indian Reservation, Big Horn County, is a bed of soft yellow sandstone about 100 feet thick, which is the equivalent of the Shannon sandstone[3] of Wyoming. This sandstone in all probability occupies the same stratigraphic position as the Eagle sandstone which is typically developed 60 miles to the northwest at Billings.

An attempt was made to establish the equivalency of the Eagle and Shannon horizons. The Shannon (Locality 1) can be traced northward to the vicinity of Hardin, but from there westward 15 miles to Spring Creek, where the first outcrop of undoubted Eagle occurs, it is not possible to follow definitely the horizon because of the plains type of topography. It may be said, however, that at irregular intervals it is possible to find sandy areas which may be outcrops of beds at the Shannon-Eagle horizon. If the Shannon and Eagle are equivalent, the Eagle probably is not at the base of the Montana group, since the Shannon is above the Pierre-Benton contact.[4]

[1] W. H. Weed, "Geology of the Fort Benton Quadrangle, Montana," *U. S. Geol. Survey*, Geol. Atlas, folio 55.

[2] Eugene Stebinger, "Anticlines in the Blackfeet Indian Reservation, Montana," *U. S. Geol. Survey*, Bull. 641 (*c*), 1917.

[3] C. H. Wegemann, "The Salt Creek Oil Field, Wyoming," *U. S. Geol. Survey*, Bull. 452, pp. 37–83, 1911.

[4] C. H. Wegemann, "The Salt Creek Oil Field, Wyoming," *U. S. Geol. Survey*, Bull. 670, 1918.

The Eagle sandstone thins out eastward and is not present in Montana east of a line drawn from Hardin through the east end of the Cat Creek anticline to the Little Rocky Mountains. Its time equivalent in eastern Montana is in the shales of the lower Pierre. In the area between the Pryor and Beartooth mountains (Locality 2) the Eagle can be recognized. Hare's section[1] in the Elk Basin field gives the thickness of the Eagle as 300 feet. In the writers' section at Bridger, Montana, 377 feet of beds are assigned to the Eagle. At Elk Basin and Bridger the Eagle has a bed of minable coal near the top.

So far as known, the Eagle underlies the Livingston formation in all the Crazy Mountain region (Locality 3). Where it is exposed on the Ringling and Potters Basin anticlines, the Eagle is *andesitic*. In the Potters Basin area there is a bed of coal in the formation.

In the Trail Creek, Livingston, and Electric coal fields, farther south,[2] the Colorado group is conformably overlain by a series of sandstones and shales, reaching, in the Electric coal field, a thickness of 1,000 feet. The basal member of this series of rocks is in all probability the equivalent of the Eagle to the north and east. The distance from the base of the lowermost member of the sandstone series to the coal beds in the Electric field is about the same as from the base of the Eagle to the coal at Bridger. Coal also occurs near the top of the Eagle at Nye in the upper Stillwater Basin. In the Crazy Mountains area the Eagle has a thickness of 175 to 300 feet.

In the region between the Big Snowy and Big Horn mountains (Locality 4) the Eagle is made up of the characteristic three members. The upper member is a massive sandstone which is locally replaced by shale. The middle member is shale with thin sands and local coal beds. The lower, or Virgelle sandstone, is a massive, cliff-making sandstone. The thickness in this area is 130 to 300 feet. On the west dome of the Cat Creek anticline the thickness of the Eagle is 115 feet, but it thins out very rapidly to the east and is entirely gone a few miles east of Musselshell River.

[1] E. T. Hancock, "Geology and Oil and Gas Prospects of the Lake Basin Field, Montana," *U. S. Geol. Survey*, Bull. 691, 1918.

[2] W. R. Calvert, "Geology of Certain Lignite Fields in Eastern Montana," *U. S. Geol. Survey*, Bull. 471, 1912.

The Eagle-Virgelle becomes thinner from west to east across northern Montana and is absent on the east flank of the Little Rocky Mountains. The formation pinches out very abruptly in this area, a feature which is characteristic of its eastern edge. From the Little Rockies westward the Virgelle has a gradually increasing thickness until near Conrad in Pondera County, its thickness is 383 feet. In this area the formation is made up of yellow to gray sandstones and clay shales. The sandstone of the upper half of the formation contains many ferruginous concretions. In some areas west of the Sweetgrass arch the upper member of the Virgelle is capped by a thin magnetite sandstone. In the area north of the Blackfoot Reservation, in Canada,[1] the equivalent of the Virgelle is found in the lower part of the Belly River series. In areas farther east the Canadian equivalent of the Eagle is called the Milk River sandstone.

Colorado group.—The term Colorado Group will be used in this paper to designate the strata between the Eagle sandstone or its equivalents and the Dakota sandstone or its equivalents. The formations making up the Colorado group in Montana are often referred to collectively as the Colorado shale. The rocks of this group are composed largely of dark marine shales. Intercalated with these shales are relatively thin sandstones, thin local limestones, and at least one conglomerate which is fairly widespread. In passing from west to east, the sandstones are gradually replaced by shale.

It has been suggested earlier in this paper that the Eagle sandstone is somewhat above the base of the Montana group and that the upper part of the shale usually referred to as Colorado is of Montana age, a division based on fossil evidence.[2] The fact that the Shannon and Eagle are homotaxic equivalents indicates the same thing. In the marine shales of the upper part of the Colorado, such a division is impracticable and will not be attempted here. The lower contact of the Colorado has been placed at the top of the persistent sandstone which directly overlies the Lower Cretaceous, that is, at the top of the Dakota sandstone.

[1] D. B. Dowling, "The Southern Plains of Alberta," *Geol. Survey Canada*, Mem. 93, 1917.

[2] W. T. Thom, Jr., *U. S. Geol. Survey*, Bull. 736 B. 1922.

The rocks of the Colorado group are referred to by the same name in adjacent regions except in Canada where the group is called Niobrara-Benton shales. That part of the Colorado group above the Mowry shales in the Crow Reservation has been divided by Thom and Moulton into Niobrara, Carlile, and Frontier, which have an aggregate thickness of 1,000 to 1,400 feet. These formations are not readily distinguished in the field. According to Wegeman, the distance in the Salt Creek Oil field from the top of the Mowry to the base of the Shannon is 2,700 to 3,000 feet. This interval at the Montana-Wyoming line is occupied by about 1,400 feet of shale. Farther north on Pryor Creek, the distance from the top of the Mowry to the base of the Eagle is about 1,320 feet. In the Bridger area to the west, the distance from the Mowry to the base of the Eagle is 1,923 feet. In the Elk Basin region to the south where all the rocks in the interval are referred by Hares to the Niobrara, Carlile, and Frontier, the interval is about 1,800 feet. The Niobrara and Carlile can be differentiated on the Frannie anticline, but are not distinguishable at Bridger, Montana.

The sands of the Frontier formation which produce oil at Elk Basin, outcrop in the area around Bridger and may be followed northward until they disappear on the northwest flank of the Pryor uplift. North of Red Butte dome, in Carbon County, a thin, black pebble conglomerate containing fish teeth was found at the base of the Frontier formation.

The Mowry shale is easily distinguished at the outcrop in southern Montana, both east and west of the Big Horn and Pryor uplifts. It is a platy or splintery gray sandy shale containing fish scales. In the Crow Reservation the thickness is 160 to 275 feet. In the area between the Pryor and Beartooth mountains the thickness is from 150 to 200 feet.

The Thermopolis shale can be differentiated in southern Montana. Its thickness is from 500 to 775 feet. On Pryor Creek, north of the Pryor Mountains, there is a sandy zone near the center of the Thermopolis which may be the equivalent of the Muddy sand.

The total thickness of the Colorado in southern Crow Reservation is slightly in excess of 2,000 feet, while in the area around Bridger, the junior author measured a thickness of 2,780 feet.

The rocks of the Colorado group in the region surrounding the Crazy Mountains contain coarser-grained sediments than they do farther east. The section near Livingston is made up of green and dark gray shales intercalated with sandstones, also dark colored. The senior author found a conglomerate 25 feet thick, 1,243 feet from the base of the Colorado in this section. Farther north the outcrop of the upper part of the Colorado on the flanks of Ringling anticline contains several beds of green to gray sandstone and a black pebble conglomerate one foot thick, at about the same distance above the base as the conglomerate at Livingston. East of the Crazy Mountains on the Big Elk dome, Bowen[1] found several sandstones in the Colorado, one of which, the Big Elk sandstone member, is 250 feet thick and slightly conglomeratic. This sandstone is in the approximate stratigraphic position of the Frontier formation. The sandstones of the Frontier at Bridger and at Big Elk cannot be directly correlated but it is possible that the beds are continuous farther west, where the Colorado is under cover. The Mowry shale is not distinguishable in the area around the Crazy Mountains. The thickness of the Colorado group is 2,775 feet near Livingston and 2,507 feet near Ringling. In passing from the Crazy Mountains to the Snowy Mountains area, the sediments making up the Colorado group are finer grained throughout, and the sands which are not replaced by shale are thinner. Beds of limy concretions are more common. The Colorado exhibits variations in thickness in central Montana. Calvert[2] in his section 9 miles east of Garneill, assigns to the Colorado 2,360 feet of beds. Its thickness on the Cat Creek anticline is about 1,800 feet.

The Frontier is represented in the Cat Creek area by the Sage Hen and Mosby sandstones[3] and the shales between them. In this area the Mosby sandstone is about 1,170 feet above the base of the Colorado group in about the same stratigraphic position as

[1] C. F. Bowen, "Anticlines in Part of the Musselshell Valley, Montana," *U.S. Geol. Survey*, Bull. 691, 1918.

[2] W. R. Calvert, "Geology of the Lewistown Coal Field, Montana," *U. S. Geol. Survey*, Bull. 390, 1909.

[3] C. T. Lupton and Wallace Lee, "Geology of the Cat Creek Field, Fergus and Garfield Counties, Montana," *Amer. Assoc. Petrol. Geol.*, Bull. V (1921), p. 252.

the Big Elk sandstone of which it is probably the equivalent. In Devils Basin there is a sandstone 1,240 feet above the base of the Colorado which Shaw[1] correlated with the Mosby. Another sand 125 feet above this, is believed to be the equivalent of the Sage Hen member of the Cat Creek section and to mark the top of the Frontier formation. The Mowry, which cannot be recognized in the Big Elk dome, can be distinguished in Devils Basin and Devils Pocket folds and in the area around Grass Range where it is about 80 feet thick. In Devils Basin the Mowry shale is 850 feet above the base of the Colorado group and has a thickness of 143 feet. The occurrence of the conglomerates at Bridger, Livingston area, Ringling, and Big Elk and the Mosby sandstone at Cat Creek is such as to suggest the possibility that they are all at the same horizon.

In passing from the Snowy Mountains area to the Little Rocky Mountains area (Locality 5) there is no marked lithologic change in the rocks making up the Colorado group. The group contains, in the Little Rocky Mountains area, 1,150 feet above the base, a lithologically separable zone, 66 feet thick with thin sandy limestones at top and bottom and calcareous shales between. Fossils collected from these sandy limestones were referred to the Mosby horizon by T. W. Stanton, of the United States Geological Survey. The evidence while inconclusive, indicates that the conditions which resulted in the deposition of the Frontier formation in Wyoming and southern Montana caused also the deposition of beds lithologically somewhat similar over wide areas in central and northern Montana.

The Mowry shale is readily distinguished in the Little Rocky Mountains region. It occurs 730 feet above the base of the Colorado group and is 80 feet thick where measured. This shale is lighter colored on weathered surfaces and is harder than in southern Montana, but characteristically it is black on fresh fracture and contains great numbers of fish scales. The total thickness of the Colorado in this region, as measured by the writers, is 2,390 feet.

From the Little Rocky Mountains area westward the Colorado is progressively sandier in the basal part. On the Rocky Mountain

[1] E. S. Shaw, personal communication.

front in northern Montana, the basal 600 feet, known as the Blackleaf member of the Colorado[1] contains a comparatively large proportion of sandstone. That part of the Colorado group above the Mowry horizon cannot be divided in the Sweetgrass arch. About 800 feet above the base of the Colorado is found a gray, platy, sandy, hard shale, containing fish scales, which is believed to represent the Mowry. This shale is about 50 feet thick. It is interesting to note that east of the town of Belt there is a 30-foot bed of volcanic ash in the Colorado, 550 feet from the base. The material weathers to a gray color very similar to the Mowry. The thickness of the Colorado on the Sweetgrass arch is about 1,725 feet. The group is thicker to the southwest and Stebinger[1] gives the thickness in the Sun River area as 1,800 feet plus.

Dakota sandstone.—It seems advisable to discuss the Dakota sandstone or its equivalents in Montana. The literature contains very little reference to the Dakota in this state and Fisher and Calvert in their work on the Kootenai around Great Falls and Lewistown concluded that the Dakota was not present. Darton grouped the basal sandstone of the Upper Cretaceous with the Lower Cretaceous along the east side of the Big Horn Mountains under the name of Cloverly. This grouping of sandstones is natural, but if we understand the meaning and proper application of the term Dakota, as defined first by Stose[2] and later by Lee[3], it is the lowest or basal Upper Cretaceous sandstone formed on the beach of an encroaching sea, and while it cannot be called a time-unit formation, it is certainly a lithologic and homotaxic unit representing the inauguration of marine conditions over a large part of what is now Western North America.

In order to limit formations intelligently it is necessary to take into account not only their fossil content and lithology, but also their stratigraphic position, the mode of their formation, and the

[1] Eugene Stebinger, "Oil and Gas Geology of the Birch Creek-Sun River Area, Northwestern Montana," *U. S. Geol. Survey*, Bull. 691, 1918.

[2] G. W. Stose, "Geology of the Apishapa Quadrangle, Colorado," *U. S. Geol. Survey*, Geol. folio 186, 1912.

[3] W. T. Lee, "Relation of the Cretaceous Formations to the Rocky Mountains in Colorado and New Mexico," *U. S. Geol. Survey*, Prof. Paper 95, 1915.

other physiographic and geographic conditions attending their deposition. A sandstone occurs conformably at the base of the Colorado group over most of Montana. This sandstone ranges in thickness from 10 to 120 feet. Its average thickness is about 50 feet, and over much of the area where it is known, its thickness is very uniform and near the average. It exhibits many of the characteristics of the Dakota sandstone farther south, though it is somewhat softer and more easily eroded. In many places it contains the worm markings and concretionary masses of typical Dakota. This sandstone has been grouped with the Cloverly in the southern part of the state; in the Musselshell valley, and in the vicinity of Great Falls it has been described as the lowest member of the Colorado group. In the Crow Indian Reservation (Locality 1), its thickness ranges from 20 to 116 feet. It is overlain by dark gray Thermopolis shale and rests on lighter colored shale, usually red. On the west slope of the Pryor Mountains (Locality 2) it is brown to gray in color and ranges in thickness from 55 feet near Bridger to 110 feet near the Wyoming line. The sandstone is present in all outcrops noted around the Crazy Mountains. It has a thickness of 65 feet south of Livingston and of 48 feet in a drill hole south of Ringling. East of the Big Snowy Mountains its thickness ranges from 55 to 65 feet and it grades upward into Colorado shale. In the Cat Creek field, where it is known as the Cat Creek sand, it rests on a white fire clay or on red or gray shale as shown by the well logs. Its average thickness here is 55 feet. In the vicinity of the Little Rocky Mountains, the basal Upper Cretaceous sand is from 4 to 16 feet thick and grades upward into shaly sandstone and sandy shale of the Lower Colorado. In the Great Falls district according to Fisher[1] there is sandstone at the base of the Colorado group which is thin-bedded, platy, and grades upward into typical Colorado shale. These features are to be expected in sandstones formed like the Dakota. Its thickness varies from 25 to 100 feet. In wells drilled in the Sweetgrass arch during the last year, the Dakota has a thickness ranging from 10 to 26 feet. It lies upon the red and gray shale of the Kootenai.

[1] C. A. Fisher, "Geology of the Great Falls Coal Field, Montana," *U. S. Geol. Survey*, Bull. 356, 1909.

In the northern part of the state this sandstone has been variously assigned to the Kootenai and Colorado and to the lower part of the Blackleaf member of the Colorado group. It is admitted by the writers that the Blackleaf member may be somewhat younger than the Dakota of Wyoming and Colorado, but the lower part of it is, nevertheless, believed to be the homotaxic equivalent of the Dakota sandstone.

LOWER CRETACEOUS (COMANCHEAN)

The Lower Cretaceous series in Montana consists of fresh and brackish water sediments of continental origin with a surprisingly uniform thickness of from 600 to 700 feet. It is represented in southern Montana by the lower part of the Cloverly and probably also by the Morrison, and in northern Montana by the Kootenai and Morrison. There is no plainly marked unconformity between this series and the overlying Upper Cretaceous, but a hiatus may exist.

The type section of the Cloverly was measured by Darton near Cloverly post-office, Wyoming, on the southwest flank of the Big Horn Mountains at a point where the series was very thin[1]. His section is as follows:

	Feet
Light buff sandstone	10
Tan-colored sandstone	10
Maroon clay	4
Reddish and tan-colored sandy clay	10
Drab sandy clay	10
Deep maroon sandy clay	20
Hard, tan-colored sandstone	3
Deep maroon and purple variegated clays	12
Lenses of maroon sandstone	3
Deep maroon sandy clay	20
Olive-green, soft, cross-bedded sandstone with hard layers	11
	112

Darton suggests the correlation of the upper sandstone with the Dakota sandstone of the Black Hills section, the middle shale

[1] N. H. Darton, "Geology of the Big Horn Mountains, Wyoming," *U. S. Geol. Survey*, Prof. Paper 51, 1907.

portion with the Fuson formation and the lower sandstone with the Lakota, and states that on this basis "it represents the later deposits of the Lower Cretaceous and the earliest deposits of the Upper Cretaceous." It is this correlation that the writers favor for Montana and believe that the shale member below the upper sandstone in the Crow Reservation is the equivalent of the upper Kootenai of northern Montana and the thick conglomeratic sandstone below it is the equivalent of the thick sandstone of the Kootenai of the central and northern part of the state as will presently be shown.

The variegated shale between the upper and lower sandstones of the Cloverly of the Crow Indian Reservation contains the same maroon and white mudstones as the type Fuson of the Black Hills. It also contains some thin lenses of yellow to white sandstone and in several places green and purple shale have been noted. Its thickness is from 105 to 151 feet on the east side of the Pryor Mountains, and on the west side of the same range reaches a thickness of 313 feet. The sandstone at the base of the Cloverly (Lakota) is conglomeratic around the north end of the Big Horn Mountains where its thickness ranges from 58 to 130 feet. On the west flank of the Pryors it is composed almost entirely of black and white chert pebbles. Its thickness a mile south of Bridger Canyon is only 10 feet.

Farther north these strata are grouped in the Kootenai, but a sandstone, conglomeratic in many places, with a thickness of 50 to 120 feet is found in the lower or middle part of the Kootenai wherever the formation has been observed, and may represent the Lakota.

Kootenai formation.—South of Livingston the Kootenai has a thickness of 577 feet where, according to Calvert,[1] it has a conglomeratic sandstone 51 feet thick, 175 feet above its base. In this area as over most of the southern and central parts of the state, the shales are predominantly red in color. The thickness of the Kootenai near Tyler on the east side of the Big Snowy Mountains is 554 feet, of which the upper 400 feet is made up of thin, lenticular sandstone beds and variegated shales. Below the thick sandstone

[1] *Loc. cit.*

is about 100 feet of variegated shales usually assigned to the Kootenai. The prominent sandstone which is here 100 feet above the base of the formation occurs in the Judith Basin and Great Falls areas from 60 to 100 feet from the base. It is in the carbonaceous zone immediately below this sandstone that the coal of the Lewistown and Great Falls fields occurs.

The Kootenai is not exposed between the Judith Mountains and the Little Rocky Mountains to the north. In the exposures in the Little Rocky (Locality 5) and Bearpaw mountains, the Kootenai is thicker than in the Snowy Mountains region and contains less red shale. There is a sandy zone near the center of the formation which may be the equivalent of the sandstone somewhat nearer the base in the Lewistown coal field. The Kootenai in the Sweetgrass arch (Locality 6) is much darker than in the Great Falls coal field to the south, and resembles the section exposed in the Little Rocky and Bearpaw mountains. The formation in this area contains red shales which grade laterally into dark shales. The Sunburst sand which is productive of oil and gas in one area is in this formation. The Kootenai is much thicker toward the north and in the Alberta coal fields it has a reported thickness of over 1,100 feet.[1]

It seems likely that the variegated shales below the thick conglomeratic sandstone should be grouped with the Morrison, though the writers have not yet obtained a sufficiently large number of data to either prove or disprove this possibility.

Morrison formation.—Underlying the Cloverly in southern Montana and the Kootenai in central Montana is the Morrison formation. The formation is made up of a series of brackish and fresh-water sandstones, shales, and thin, gray-white limestones.

The thickness of the Morrison in the Crow Reservation is 100–150 feet and has as the predominating material a hard, greenish-gray shale. There are, however, pink and purple shales and clays exhibited on the outcrops so that it is easily distinguished in the field. The sandstones are grayish-green, white, and yellow. Some thin ash-colored limestones are also present. To the west in the Pryor-Beartooth Mountain area (Locality 2), the Morrison has thickened

[1] D. B. Dowling, *loc. cit.*

to 294 feet. The top and base of the formation are marked by sandstones. The basal sandstone is 115 feet thick and is yellowish to tan in color. The shales of the Morrison are buff, yellow, and pink, and contain an occasional irregular mass of sandstone. The upper sandstone is buff, fine-grained, and soft, and has a thickness of about 50 feet.

Calvert gives the thickness of the Morrison in the Electric coal field as 185 feet.[1] Lithologically, it is similar to the section just described. Whyman[2] reports that the formation is not present in the area around Ringling. Sickler's[3] section of the Morrison on Button Butte in Fergus County is, with the exception of a 5-foot limestone, made up of red, green, and gray shales. The thickness of the formation in this area is 115 feet. No rocks which can be recognized as Morrison, as the term is now used, have been found in the Little Rocky Mountains or farther north. The Morrison has a thickness, according to Fisher,[4] of 120 feet in the Great Falls coal field.

Both the Kootenai and Morrison formations contain dinosaur and plant fossils which, according to many paleontologists, indicate their Lower Cretaceous age, though some paleontologists place the Morrison as latest Jurassic.

JURASSIC

Sundance-Ellis formation.—There is little question that the Sundance and Ellis are equivalent formations. They are similar lithologically and contain marine fossils in abundance, which indicate that they are Upper Jurassic in age.

In the Crow Reservation, the formation consists of a series of gray sandstones, dark, greenish shales, and greenish-gray limestones. There are thin beds of hard, sandy limestone in the upper part of the formation. The formation is inconstant in character. The thickness in the Crow Reservation is about 250 to 350 feet. In the Pryor-Beartooth area the Ellis-Sundance has a thickness of 448 feet. The lower part of the formation is limestone succeeded above by pink and gray shales with an occasional thin fossilferous lime-

[1] *Loc. cit.*

[2] L. O. Whyman, personal communication.

[3] J. M. Sickler, personal communication.

[4] *Loc. cit.*

stone. The gray shales contain many belemnites and gryphaea. In the Electric coal field the Ellis is made up of 236 feet of limestone and shales capped by 41 feet of sandstone, giving a thickness of 277 feet. According to Whyman,[1] the formation is missing in some areas north of Livingston, but this was not verified by the writers.

The Ellis in the area east of the Snowy Mountains has a thickness of about 150 feet, and is made up of yellow limestones and shales with a 40-foot sandstone at the top. The thickness of the formation in the Judith Basin region is variable, ranging from 65 to 440 feet, according to Calvert.[2] In the Little Rocky Mountains the Ellis is made up of limestone and limy shale. The color is greenish-gray to buff. The thickness is about 250 feet. In the Kevin-Sunburst field it is about 200 feet thick, and contains a sandy limestone near its base which is the source of part of the oil production of the area.

TRIASSIC (?)

Chugwater formation.—The Chugwater formation, as developed in Wyoming, occurs only in southern Montana. It outcrops around the north end of the Big Horn Mountains and on the flanks of the Pryor Mountains, but is not present around the Belt and Big Snowy mountains or in northern Montana.

The formation is mainly of soft, fine-grained, massive, brick-red sandstones with some red shale. There are extensive beds of gypsum near the top and bottom of the formation, and a few thin-bedded limestones occur at varying intervals. Darton[3] collected fossils in it in Wyoming which indicated that the upper part is probably of Triassic age. The thickness of the Chugwater on Lodge Grass Creek in the Crow Indian Reservation is 800 feet.

The most northerly exposures of the Chugwater on the north flank of the Pryor Mountains show that the formation has thinned to 200 feet in a comparatively short distance. The exact northerly extent of the Chugwater is unknown.

PERMIAN (?)

Embar formation.—The evidence as to the presence or absence of the Embar formation in the Crow Reservation is conflicting.

[1] *Loc. cit.* [2] *Loc. cit.* [3] *Loc. cit.*

Darton[1] states that the Embar is not present in this region and is found no farther north than the west fork of Powder River on the northeast side of the Big Horn Mountains. Condit[2] states that he was able to trace the Embar beds from the type section at Embar post-office, northeastward until they graded laterally into beds that were included in the Chugwater by Darton. This would indicate that the Embar formation as developed farther west and south is, at least in part, equivalent to the basal portion of the Chugwater red beds of the Crow Reservation.

In the section measured on Little Big Horn River by Sickler and Romine,[3] there are 39 feet of shale, sandstones, and limestones which they correlate with the Embar. These beds thin northward and could not be mapped as a definite horizon north of Big Horn River. Directly underlying the Chugwater east of Pryor Creek and on Blue Water Creek, on the northwest flank of the Pryor Mountains, was found a thin bed of gray limestone which may represent the Embar in these areas.

The age of the Embar is variously placed as late Pennsylvanian or Permian.

PENNSYLVANIAN (?)

Tensleep sandstone.—In areas where the Embar is missing in southern Montana, the Chugwater is underlain by the Tensleep of Pennsylvanian age. The Tensleep sandstone is buff to white in color and has, near the top, beds sufficiently calcareous to be called sandy limestone or limy sandstone. The limy beds are particularly noticeable in the western part of the area. The sandstone which is marine is usually made up of nearly pure quartz grains and is cross-bedded and occurs in thick beds. On some outcrops these sandstones exhibit a peculiar jointing which breaks the rock into diamond-shaped blocks as viewed from a direction parallel to the joint planes. The thickness of the Tensleep in the Crow Reservation varies from 80 to 150 feet.

Amsden formation.—Directly below the Tensleep and overlying the Madison limestone in southern Montana is the Amsden forma-

[1] *Loc. cit.*

[2] D. Dale Condit, "Relations of the Embar and Chugwater Formations in Central Wyoming," *U. S. Geol. Survey*, Prof. Paper, 98, 1916.

[3] J. M. Sickler, T. B. Romine, in a personal communication.

tion which is made up of a series of red shales, sandstones, limestones, and cherty limestones. It is late Mississippian or early Pennsylvanian in age. This formation is about 90 feet thick at the Montana-Wyoming line on the east side of the Big Horn Mountains, and the section on Blue Water Creek shows the thickness at that place to be 73 feet. It is probable that the thickness of the formation does not vary greatly beyond the limits indicated in the measured sections in this locality.

Quadrant formation.—The type section of the Quadrant was measured on Quadrant Mountain in Yellowstone Park by Weed,[1] where, according to Condit,[2] it contains strata of both Pennsylvanian and Mississippian age. It occupies the same stratigraphic position in central Montana as the Embar, Tensleep and Amsden series does around the north end of the Big Horn Mountains. One of the outstanding features of the Quadrant west of a meridian through Yellowstone Park is the presence of a quartzitic bed ranging in thickness from 350 to 450 feet but becoming thinner eastward. This quartzite is separated from the Madison limestone below by an extremely variable thickness of shale, limestone, and some sandstone. Above the quartzite is another variable member of limestone and shale, which, from fossils identified by Henderson,[3] is Pennsylvanian in age. Eastward the quartzite is thinner, less hard and more like a true sandstone. In all probability it correlates with the Tensleep sandstone of Wyoming. The lithology is sufficiently similar, the fossils indicate Pennsylvanian age, and in each case, the stratigraphic position is the same.

A complete discussion of the Quadrant in this paper cannot be given, not alone from the lack of space, but from the lack of specific data on this series of strata which seem to present such a diversity of paleontologic and stratigraphic facts. In the opinion of the senior author, the so-called Quadrant of Montana contains at least three formations in some areas and two in others. An unconformity exists at the base where it rests on Madison limestone,

[1] W. H. Weed, "Geology of the Southern End of the Snowy Range," *U. S. Geol. Survey*, Mon. XXXII, 1899.

[2] D. Dale Condit, "Relations of Late Paleozoic and Early Mesozoic of Southwestern Montana," *U. S. Geol. Survey*, Prof. Paper 120, 1918.

[3] Junius Henderson, in a personal communication.

another unconformity is present at the base of the thick quartzite to the west and is indicated by the conglomerate at the base of the thick sandstone series (Tensleep) around the Snowy Mountains. It seems likely that another unconformity exists above the Tensleep, expressed as an overlap on the north side of the Little Belt Mountains, where this sandstone is absent.

The lack of continuity in the outcrops, the variable thickness of the series, and the striking changes in lithology in the series at different points and the haphazard collection of fossils from a wide vertical range, have all tended to keep the age and correlation of the Quadrant in obscurity. It contains many showings of oil in various localities and deserves much careful study, not only for economic purposes, but for scientific reasons as well.

The writers will not attempt a detailed description of the Quadrant in various localities in this paper, but refer the reader to the plate of sections which gives the thickness and character of the strata at different points and tentative correlations of some of them.

DISCUSSION

J. S. IRWIN: How far north of the Wyoming-Montana line can the Pierre (Montana) shales be recognized below the Eagle sandstone and above shales of Colorado age?

MAX BAUER: I understand that fossils of Montana age have been recognized by T. W. Stanton in shales below the Eagle sandstone in Montana, but the separation of the shale is difficult and hardly mappable, and, over a greater part of the state, the Eagle sandstone is taken as a base of the Montana group. The shale below the Eagle, which might be assigned to the Montana group, undoubtedly thins rapidly north of the Wyoming line. In the southern part of the Crow Reservation W. T. Thom, Jr., has made a separation of these shales and called it the Telegraph Creek formation, which he assigns to the Montana group.

E. W. KRAMPERT: Is there any particular regularity in the distribution of the sands in the Colorado group, that is, the sands which correspond to the Wall Creek sands of Wyoming?

MAX BAUER: There is a regularity in their stratigraphic position. If the question means whether the Wall Creek sands can be traced across Montana or not, I would say that a thin sandstone, which is in some places conglomeratic, has been found over most of the central and eastern part of Montana at a corresponding interval above the base of the Colorado group. This sandstone is known as the Big Elk, part of which correlates with the Mosby sandstone.

GEOLOGICAL NOTES

THE SABINE UPLIFT

The Sabine Uplift has been ably described by several authors since Harris, whose ideas have been recently summarized by Sidney Powers[1] before this Association. These authorities are all of the opinion that the uplift is limited to that large geanticlinal fold whose axis extends in a northwest-southeast direction between Caddo and Bull Bayou. Powers assumes that other structural highs such as Homer and Monroe are of independent origin. With these ideas the present writer cannot wholly agree, and in support of his differing conclusions submits the two maps accompanying this paper (Figs. 1 and 2).

Figure 1 is a structure map of north Louisiana and Arkansas based upon the attitude of the Nacatoch sand or its equivalent, as determined by well logs. From this map it appears to the writer as self-evident that there are three major northwest-southeast axes, of which the Sabine is merely the highest structurally. These axes at a later time have been crumpled by compression applied at right angles to the strike of the original folds. (Fig. 2.)

Powers concludes on the basis of stratigraphy that the first uplift took place in early Claiborne time, but that later and more intense folding followed the Oligocene period. These ideas appear to fit the conditions shown by the chart (Fig. 2) very well. The last folding may have been coincident with the collapse of the Mississippi Embayment. If the crumpled axes be straightened out, a somewhat definite measure may be had of the lateral compression accompanying this collapse. The pressure from the direction of the sinking and contracting Gulf prism of sediment no doubt caused this arcuate folding around the nose of the positive Ouachita shield.

There may have been more or less tangential movement accompanying this post-Oligocene crumpling, which caused lateral tension within the area now marked by the synclinal salt domes of northern Louisiana. This would have set up lines and points of weakness presumably favorable for the formation of salt domes. However, the great thickness

[1] Sidney Powers, "The Sabine Uplift," Louisiana, *Am. Assn. Petrol. Geol., Bull. IV*, No. 2, 1920.

of black shales occurring in the Midway within this same area, and other evidence that the beginning of the formation of these salt domes was in Upper Cretaceous times, makes it seem more probable that this area of weakness already existed, and was perhaps only accentuated by later folding and crumpling.

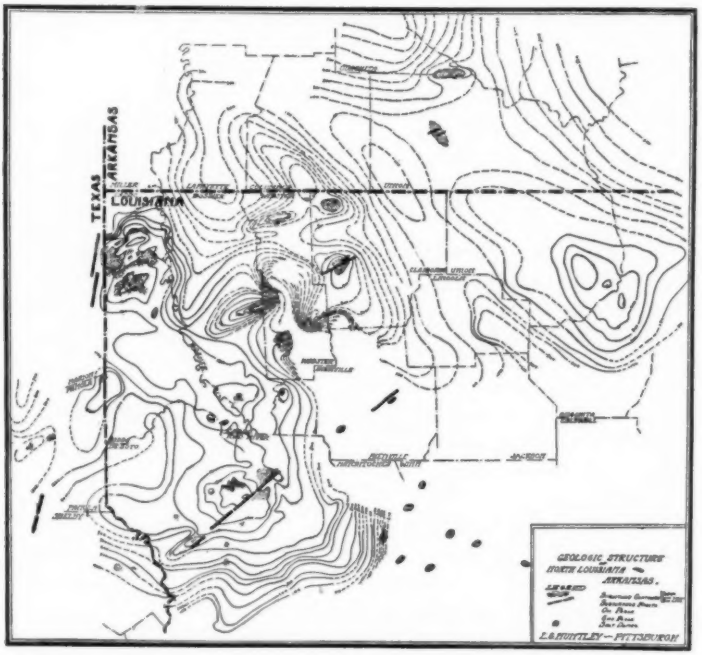

FIG. 1

The main effects of this sequence of folding on the accumulations of oil and gas in north Louisiana and Arkansas seem to be the following:

1. Oil and gas during Cretaceous times would have tended to accumulate in sands erratically on the basis of location of good reservoirs close to good source beds. Possibly a slow movement toward the Ouachita shore lines, with some oxidation to heavy oil in that zone.

2. Accumulation of oil and gas in pools along the three northwest-southeast axes during Claiborne time and later, both on the basis of origin, reservoir, and specific gravity.

3. Redistribution of oil and gas on the main axes by the post-Oligocene crumpling. Thus gas pools might have been separated structurally from their corresponding oil pools. Faulting and vertical migration and filtration may have altered the gravities of crudes in certain areas.

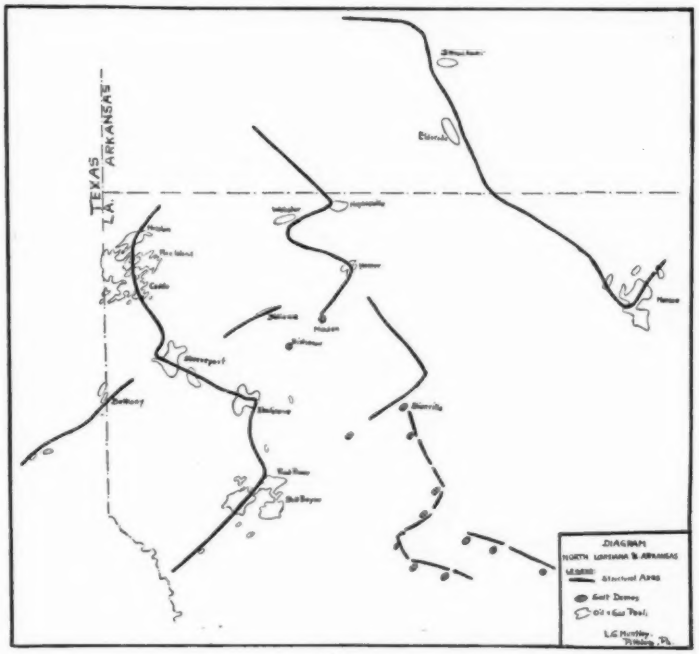

FIG. 2

There would be expected less amounts of both oil and gas on these later northeast-southwest spurs than on the main axes which antedate the crumpling. If the assumption that this lateral movement accompanied the crumpling of these older axes is correct, it would seem that there has been introduced into petroleum geology a unique example of folding which has hitherto been looked upon as of only minor importance in most other fields. Cross folds and bent axes are known and have been described, but few examples offer the opportunities for study as do those of north Louisiana.

L. G. HUNTLEY

FRICK BUILDING, PITTSBURGH, PA.

OIL AT LULING, CALDWELL COUNTY, TEXAS

During the summer of 1922, oil was discovered in what promises to be commercial quantity on the Rafael Rios farm, John Henry Survey, six miles west of Luling, Texas. The facts as to the discovery are worthy of record here not only because discoveries of petroleum should always be recorded accurately and in detail, but because this particular discovery is a direct result of geologic investigation.

The new well is the property of the United North and South Oil Company, which in turn is largely owned and controlled by its president, Mr. Edgar B. Davis, a capitalist who has previously been interested principally in rubber cultivation and manufacture. Mr. K. C. Baker, vice-president and general manager, is directly responsible for the conduct of the business of the United North and South Oil Company, and is to be credited with much of the company's attainment. Mr. Baker has long been associated with Mr. Davis, and was at one time a forester in charge of East Indian rubber plantations for his chief.

Mr. Davis' original venture in oil started some three years ago in Gonzales County, Texas, and was wholly unsuccessful as well as discouragingly expensive. That he should have persisted, after this initial failure in a game which seemed highly speculative to this rather conservative business man, must be attributed, I think, to Mr. Davis' good sportsmanship. He was unwilling to accept defeat. Mr. Baker, who had come out to Texas to try to save something from the Gonzales County mishap, and had in the meantime secured a remarkable grasp of the technique of petroleum-finding, doubtless influenced Mr. Davis materially in his decision to continue his adventure.

However this may be, the renewed attempt to discover oil began at once under Mr. Baker's direction, and was initiated by the employment of a geologist to assist in guiding the new exploration. For the position of geologist, Mr. Vernon Woolsey, who had already spent considerable time and effort in Texas, was chosen. One of Mr. Woolsey's earliest assignments included some territory in Caldwell County, on which he discovered a fault striking with the general strike of the country and uplifting the beds on the side toward the regional dip. Mr. Woolsey recommended the upthrow-side of this fault as likely for petroleum accumulation, and it is on the upthrow-side of this fault that the discovery well was drilled. It should surprise no one, and should detract nothing from Mr. Woolsey's accomplishment that several failures were drilled before the successful well was finally obtained; the hazards of exploration in faulted territory are already widely appreciated. Nor can

the small size of the producing well obscure the importance of the discovery.

The United North and South Company owns in addition to the discovery well, some 30,000 acres along the fault against which the petroleum is accumulated and will control whatever field may develop. On one of the few small pieces of acreage not owned by them, the second producing well in the field has recently been completed.

The discovery well at Luling is 2,155 feet deep. It is producing from a limestone which is probably the upper part of the Edwards, of Lower Cretaceous age. The well starts in the lower Wilcox or possibly uppermost Midway, and the geologic section is surprisingly thin as compared with Mexia, where wells starting in lower Midway do not reach the Edwards until they are 3,400 to 3,500 feet deep. The initial production was about 100 barrels flowing by heads. The well also makes some sulphur water which, in the opinion of the owners, comes from around the casing. The second producing well is of about the same size and character but makes no water. The gravity of the oil is about 27° Baume.

The United North and South Company plans the immediate further development of their property under the direction of Mr. Baker. Mr. Woolsey is now employed in the geological department of the Atlantic Oil and Producing Company at Dallas, Texas. Recently the United North and South Company has consulted with George C. Matson and David Donohue on their geological problems and have had the advantage of the opinions of these men in making their recent locations, including the location for the discovery well.

WALLACE E. PRATT

January 22, 1923

THE RELATIVE DEPENDABLENESS OF DIFFERENT KINDS OF FOSSILS AND SOME SUGGESTIONS TO COLLECTORS[1]

Every field geologist who is more than a rock hound makes use of stratigraphy. As paleontology is one of the most useful adjuncts to stratigraphy, it behooves every geologist who works with fossil-bearing strata to make such use as circumstances permit of the organisms entombed in the rocks. The helpfulness of paleontology to stratigraphers is so obvious that it needs no brief from me. I therefore pass on to a short

[1] Read before the Petroleum Club, U. S. Geological Survey, February 6, 1923. Published by permission of the Director, U. S. Geological Survey.

discussion of the relative merits of the various kinds of fossils as aids in determining the correlation of formations.

In general, the more highly developed the organism, the shorter its persistence as a species. Conversely, the less the degree of specialization, the longer the life. Some simple species appear to have persisted with no appreciable change since early geologic time; but the complex, more sensitive forms succumbed at every unfavorable change of environment, or evolved into something different. It follows, then, that the elaborately sculptured shells or those with peculiarities of growth that distinguish them markedly from their fellows make the best guide fossils. Furthermore, one may be able to identify with assurance a tiny fragment of shell containing characteristic sculpture, whereas a much larger piece of a smooth clam or oyster may be utterly unrecognizable.

The following discussion of different phyla or classes is based chiefly on my own experience with Tertiary fossils from the Coastal Plain, from Mexico, and from the West Indies.

Foraminifera.—My acquaintance with foraminifera is slight, but a few, particularly the large orbitoids, are old and valued friends. Three genera are commonly recognized among the orbitoid foraminifera: Orbitoides, restricted to the Cretaceous; *Orthophragmina*, confined to the Eocene; and *Lepidocyclina*, which runs through the upper Eocene and Oligocene. The individual species of these orbitoid forams are excellent horizon markers. Their stratigraphic range is very narrow and many species are widely distributed. With their help it has been possible to correlate very closely the type sections in the United States with beds in the West Indies and Mexico.

Experiences with the smaller foraminifera have not been so satisfactory. Many of the species appear to have persisted for countless ages; at any rate, the differences between the older and the younger forms are so slight that they can be detected only by the ultra-specialist. Perhaps I should restrict this statement to the later Tertiary species. I am informed that study of the Cretaceous and early Tertiary species is yielding good results.

Corals.—Corals are much more satisfactory, particularly to men with headquarters in Washington, for there is a specialist here to whom one may appeal. It is a rare or imperfect coral if Vaughan cannot tell its age and approximately where it came from. Most of the corals, particularly those from the Eocene and Oligocene, are comparatively short lived. They make good horizon markers, but require critical study.

Bryozoa.—Bryozoa, also, are safest left in the hands of a specialist, such as R. S. Bassler at the United States National Museum. He has helped me many times when bryozoa were the only recognizable organisms in a collection, and on several occasions has straightened out misinterpreted field relations. Many bryozoa are good horizon markers, but there are also many generalized species that range through several formations.

Brachiopods.—There are few species of brachiopods in the Tertiary deposits of the Coastal Plain. Some of them appear to be dependable markers, but most of them have such poorly defined characteristics that one hesitates to rely upon them implicitly without support from other stratigraphic criteria.

Echinoids.—Echinoids or sea urchins are excellent guide fossils. Most of the Coastal Plain species are distinctive enough to be identified easily, and with few exceptions they were very short-lived forms. The geographic range of some of them is not so wide as one would like, but closely related species in different geographic provinces often occupy corresponding stratigraphic positions. The Cretaceous and Tertiary echinoids of the United States have been described and figured in one of the Survey monographs. As the stratigraphic position of many of the species was not known when that book was written, and as there have been important changes in correlation of certain Tertiary formations since it was published, one cannot depend upon present published data for correlation by means of echinoids. However, I hope to publish before long a table showing the stratigraphic range of the Tertiary echinoids from the Coastal Plain.

Mollusks.—Mollusks are faithful standbys in the fossil line, not because they are more abundant, but because they are commonly more conspicuous. They are big enough to see. The cephalopods have an enviable reputation for wide dispersion and short range, but there are only a few known in the Coastal Plain Tertiaries. Pelecypods and gastropods are the commonest classes of mollusks with which I have had to deal. Both are good, and it is hard to choose between them. On the whole, I prefer the gastropods because they have only one shell. It is often possible to identify a mere fragment of a gastropod, whereas a similar piece of pelecypod would be unrecognizable.

Crustacea.—Crabs and other crustacea, probably because their fossil remains are so imperfectly known, do not appear to be of much value in correlation.

Vertebrates.—My experience with vertebrates is limited to a very few species, all marine forms and good horizon markers. The vertebrates, in general, are considered reliable guide fossils.

Plants.—Many correlations based only upon plants seem to me a little questionable. Except where the floras of several successive stages are abundant and well explored, reference of the ordinary job-lot collection of a few fragments to a precise place in the geologic column is fraught with many dangers. I have known of several instances in which beds have been referred to the wrong formation because the plants in them had a wider range than supposed and because the flora of the formation to which they really belong was unknown. This fact does not imply any innate cussedness or peculiarity of plants. The same fault might be found with mollusks or any other class of organisms. It means simply that the knowledge of the flora of one formation had outdistanced that of another, so that the small collections of plants from the unknown flora were attributed to the already known flora with which they had many elements in common. To him that hath shall be given.

SUGGESTIONS TO COLLECTORS

This explanation of why paleobotanists (and paleontologists) occasionally go wrong raises the question "What can the red-necked but kind-hearted *Homo oleënsis* do to lighten the burden of the pallid parlor paleontologist and guide him past the pitfalls that beset his path?" From the fulness of my own experience as the party of the second part, with occasional changes of character to that of party of the first part, I offer some don'ts and do's to field men.

Don't restrict your collecting to localities about which you are in doubt. Unless you are sure that the fauna or flora of the formation in which you are particularly interested is already well known, try to get good collections from beds for which stratigraphic data are obtainable. Without specimens from beds of known age to use as a standard for comparison, the paleontologist cannot be sure of the correlation of beds of unknown age.

Try to make as complete collections as practicable. Better a few big collections than many scrappy ones. It is a decided advantage to have collections which contain a really representative assortment of the past population. The unity of a fauna is much more convincing when all its members are found in actual association than when the faunal census is compiled from a lot of scattered collections having only a few species in common.

Don't be afraid to tell the paleontologist what the age of your fossils is; that is, if you know it. If you are sure of the age, tell him so; if not, tell him what you suspect it to be, with the possible range in age. If he is not already so familiar with the fauna as to recognize it off-hand, you may save him days of fruitless search. If, after many hours of eye-strain in dark halls over dusty cases, the patient paleontologist reports: "This collection contains a few macerated straws and broken cup corals which seem to suggest Mint Spring age but might be Brandywine formation," don't reply: "Oh, I knew that already, the collection is from the type locality of the Mint Spring." Tell him so beforehand, lest he rise in his wrath and smite you. Take the paleontologist into your confidence. Explain your problem to him. The results will amply repay you.

A few words about labels may not be amiss. Write as specific localities as practicable on your field label. Don't be content with merely a field number and expect to write the label in the office. It is much less trouble to do it when you get the specimens. A collection without a specific locality is of practically no scientific value, and may be worse than useless.

In conclusion, almost all classes of fossil organisms have some value for correlation. The mollusks and echinoids are easiest for the ordinary or garden variety of paleontologist; the microscopic forms are safest in the hands of a specialist. If you can take the time to become proficient in the identification of fossils, it is much more satisfactory to study your own collections than to pass them along to a specialist who has no personal interest in them and to whom their study is drudgery. But one word of warning. A little paleontology is a dangerous plaything. Handle it with care.

C. WYTHE COOKE

MEETING OF THE PETROLEUM SECTION OF THE INTERNATIONAL GEOLOGICAL CONGRESS[1]

The meeting of the Petroleum Section of the International Geological Congress at Brussels, Belgium, was scheduled for August 16. For various reasons the program was not arranged in detail until the morning on which the papers were to be read, so that many who were interested

[1] The following summary, prepared from informal notes furnished by Winthrop Haynes to Sidney Powers, is presented to the Association through courtesy of Dr. Powers.—THE EDITOR.

were absent, and there was little worth-while official discussion. David White was in the chair as honorary chairman part of the morning.

All of the petroleum papers, with the exception of Ordonez' paper on Mexico, dealt with European or North African oil occurrences and were given in French, from notes in most cases. Inasmuch as M. Dalloni of Algeria was the only man to whom French was the native language, this showed the linguistic ability of the European geologists.

The following notes are arranged in the order of presentation of the papers on the program:

1. Bohdanowicz: "Sur la paragenese des gisements de bitumen avec des gisements de lignites et des phosphates."

2. Bohdanowicz: "Contribution sur la question de reserve mondial de petrole en Russie particulierement."

3. Chautard: "La geologie du petrole."

4. Dalloni: "Tectonique comparée des zones petroliferes."

The first three papers were not given owing to the absence of the authors and the opening paper, therefore, was by Dalloni. This paper is not included in the published résumés and I did not take many notes on it. He discussed the results of research and exploitation in Algeria and gave his views as to primary and secondary oil horizons there and also the relation of the oil to salt and gypsum. These subjects are fully treated in his book, *La Geologie du Petrole et la Recherche des Gisements Petroliferes en Algerie*, published by Jules Carbonel in Algiers, 1922. This was an interesting paper and well presented.

5. De Novo: "Gisements de Petrole en Espagne": This paper was read in French by Señor De Novo and was very difficult to understand owing to his Spanish accent. A résumé of this paper is in the published pamphlet of the Congress. Unsuccessful attempts at exploitation of petroliferous areas in Spain, especially in the south, as well as an unfavorable report by the Spanish geologist, Gavala, on the possibilities of commercial production, have caused the general condemnation of all Spain. The general structure of the peninsula with its many closely folded regions, with steeply inclined strata and numerous faults, as well as discontinuous formations, is unfavorable for the existence of extensive oil fields. However, study of the peninsula was undertaken with reference to (1) location of visible manifestations of oil or petroliferous matter, (2) areas of favorable geological structure, and (3) areas which combined features of (1) and (2). The results of De Novo's observations up to the present time show that there are numerous indications of the existence of petroliferous strata in the Cretaceous. He concludes that

if there are any exploitable strata they will be found in Mesozoic areas, where there are numerous seepages and also permeable and impermeable beds as well as favorable structures. As to other formations, he believes there is a possibility of finding some oil in the Tertiary, but practically no chance of getting any in the pre-Mesozoic formations, which are intensely folded.

6. Nowak: "Remarques générales sur la tectonique et le petrole des Carpathes Polonaises": The third paper of the morning was by Nowak of Krakow, Poland. This was an interesting presentation of the general structural features of the Carpathian border region and their relation to oil production. Unfortunately I took no notes on this paper and no résumé has yet been published.

7. Stansfield: "La geologie du petrole": This paper opens with a consideration of the organic origin of petroleum and its accumulation and movements underground. Then the opinions in regard to oil shales and their connections with petroleum are discussed, followed by a résumé of conditions essential for the formation of "oil pools" and mention of the anticlinal theory. The author then considers the relation of salt to oil in view of recent researches, and discusses some of the theories. He concludes with a résumé of the researches made on the chemical composition of the waters from oil wells by Rogers, Mills, and Wells.

8. Swiderski: "La structure tectonique des regions petroliferes des Carpathes orientales Polonaises": The paper by Swiderski covering in some detail the region of eastern Galicia was closely related to that of Nowak in subject-matter. The résumé of this has been printed and is briefly as follows: There is a transverse doming of the Carpathians south of the Pruth Valley, which brings the various elements of the Carpathian chain to view where they may be studied easily. In this area the author has distinguished a series of overthrust folds which overlap one on another and are named from top to bottom the "nappe de Skole," "nappe de Bitkow," "nappe de Sloboda Rungurska," and the "folds of Pokucie." Each of these tectonic units is characterized by distinctive stratigraphic and petrographic features. The richest petroliferous deposits of the Eastern Carpathians of Poland are found either in the frontal border of the recumbent overthrust beds as at Boryslaw, or in the anticlinal doming which affects many of the overthrust folds as at Bitkow, or finally in the anticlinal folds in the longitudinal depressions in front of the overthrusts.

9. Voitesti: "La geologie des gisements de petrole des regions carpathiques roumaines."

10. Voitesti: "Le sel des massifs des regions carpathiques roumaines."

Voitesti gave his two papers together and they created considerable interest and discussion. The most important points in his first paper on the geology of the oil deposits of the Carpathians of Roumania are as follows: (1) The oil comes from below on the same planes of fracture (faults) as the masses of salt, whether these faults reach the surface or not. (2) The petroliferous deposits are always formed along the margins of the fault by the impregnation of all porous strata in direct contact with the fault. (3) In areas where the fault zone has been greatly enlarged by the invasion of salt this has favored a strong migration of oil which accounts for the richest deposits of oil being found in the immediate proximity of salt masses. (4) The migration of oil along fault planes as well as the invasion of masses of salt is caused through the influence of orogenic movements, and it appears that our oil deposits assumed their present position as the result of post-Pliocene movements. (5) The beds of the superficial formations are folded in special types of anticlines "diapires"[1] under the influence of the orogenic movements. In each of the various types of folds recognized in the sub-Carpathian zone, the porous rocks have suffered a different amount of impregnation. In the domes the impregnation has been about equal on the two flanks, but in the unsymmetrical folds with overthrusts on the flanks the overturned beds have received the greatest impregnation for the longest distance, as well illustrated at Moreni oil field.

His second paper on the "Salt" contained many new and rather startling conceptions. After noting the general features associated with the occurrence of the salt, and the remarkable similarity of character wherever it occurs, and whatever strata it is in contact with, as well as the universal presence of a tectonic breccia in which are fragments of rocks older than the Flysch and including crystalline schists, granites, porphyries, Jurassic limestone, etc., which form the lower basement on which the overthrust folds of the Carpathian have been pushed, he concludes as follows: (1) The masses of salt do not belong to any of the Carpathian or sub-Carpathian formations but are older than these, and come from great depth, probably from the sub-basement, rising along lines of fracture. (2) The reason the masses of salt appear to come to the surface more abundantly in the Mio-Pliocene zone of the sub-Carpathians is because in the Carpathians proper the resistant and thick rocks of the Flysch have prevented them from rising while the relatively thin and soft rocks of the Neogene are easily pierced. (3) The age of the salt

[1] Mrazec's term to denote an anticline with central core usually of salt which has risen with a series of overlapping faults on both flanks of the fold.

cannot be Mediterranean and it cannot be placed as a part of any of the Carpathian or sub-Carpathian formations. Neither can it be Triassic, because the strata of this age which remain in the Transylvanian, Bukovina, and Dobrogean regions are very deep-water limestones with ammonites. (4) The actual position of the "massifs" of salt of the Carpathian region as well as in all regions where the salt occurs in masses is not in any way stratigraphic, but rather tectonic, and therefore cannot aid us in determining the age of the salt. (5) The invasion of these masses of salt has been along great fracture planes (faults) and has proceeded under the influence of orogenic movements, especially those of post-Pliocene date.

11. Georgalas: "Sur les hydrocarbures natifs en Grece et sur les travaux de recherches relatifs": In this paper the author classifies and summarizes the occurrences of the various hydrocarbons (asphaltic and bituminous limestones, bituminous shales and seepages of liquid bitumen and oil) in the various folded zones of Greece. He then notes the origin and migration of these deposits and also their geologic age. The most important occurrences are in the folded zone of Western Greece where the manifestations occur in Eocene strata. The only exploration recorded to date consists of nine shallow hand wells (deepest, 225 feet) in one locality. These wells encountered bituminous strata of Helvetian age and got a heavy viscous oil and impregnated sandstone beds at depth. He concludes that the researches have shown the presence of oil in the Tertiary folded zone of western Greece and thinks it not impossible that this may lead to some interesting development in the future.

12. Ordonez: "La geologie du petrole au Mexique": This paper opens with the statement of possible enormous reserves of oil territory in Mexico, which appeared in the *Bulletin* of the Mexican Geological Society several years ago. He then gives some statements regarding the producing fields and summarizes the stratigraphy of eastern Mexico. All of this is familiar to American geologists. The principal oil fields are in a line which extends for about sixty miles parallel with the coast and also with the general trend of the Sierra Madre. The productive zone is generally less than three quarters of a mile wide. He believes that various recent reports in regard to the exhaustion of the petroleum in Mexico in the near future are not well founded and notes that there are still large areas of possible oil territory which have not been explored up to the present.

Following are brief notes on Bohdanowicz' papers taken from published résumés. In the first, listed above, the author calls attention to

the phosphate contained in bituminous and petroliferous rocks from his observations in Russia and France as furnishing proof of the primary origin of the phosphate under these conditions, and notes that cannel coal contains the highest percentage of phosphoric acid of all coals. He believes that the beds of lignite, the asphaltic limestone of lower Oligocene age of the Alais region, Department of Gard, and the bituminous shales of Vargas are three facies of the same stratigraphic series. He bases this conclusion on the close relationship observed between the bituminous lignite and the oil horizons in the Embar region and also in the Lobsann deposits near Pechelbronn. He thinks it possible that the thick series of Tertiary deposits of the Basin of Alais contain petroliferous beds representing the fourth stage of bituminization.

The second paper on oil reserves notes the extreme difficulty in estimating the petroleum reserves of a country or for the world. He states that in Russia, notably at Baku and Grosny, there are new deep levels which up to the present have not been exploited, also there are extensive new fields in the Embar region as yet almost unexplored. He thinks that too little intensive research work has been done in Russia and Poland up to the present time, and he desires the Congress to fix some definite rules on which calculations of petroleum reserves shall be based. He also suggests that an International Petroleum Commission be appointed to consider the question of world-reserves of petroleum and report at the next meeting of the Congress on this matter.

WINTHROP P. HAYNES

SETTLEMENT OF THE RED RIVER DISPUTE

The Oklahoma-Texas boundary suit which has been in the courts since 1919 was settled in principle by a decision of the Supreme Court rendered January 15, 1923.

The land involved in this suit was the river-valley land on the Texas side of Red River, including the bed of the river, this land being claimed by the United States, by Oklahoma, and by Texas. By the decision of the Supreme Court the river-valley land up to the sand bed of the river remains in the state of Texas, while the sand bed of the river to the middle of the channel is adjudged to be the property of the United States. Commissioners are to be appointed by the Supreme Court to locate the boundary on the ground in accordance with this decision. Of the oil wells, ownership of which was in dispute, approximately 90 per cent remains in Texas.

It is interesting to note that at least three members of the American Association of Petroleum Geologists appeared in this suit as expert witnesses.

E. H. SELLARDS

METHODS OF DISTINGUISHING FUSED CORES

Some relatively simple yet delicate tests for the recognition of fused-rotary-drill cores from volcanic rock were outlined by C. S. Ross in Volume VI, Number 4, of this *Bulletin*. The experience of the writer with fused cores on the Gulf Coast has been that a very cursory examination is sufficient for the recognition of their character by a geologist who has had much experience with volcanic rocks, and that there is no necessity for even such simple tests. The following are a few notes for a quick, megascopic examination which, in the experience of the writer, will suffice for recognition of fused cores in the Gulf Coast.

1. To a geologist familiar with volcanic rocks, most fused cores have the looks of a slag rather than of a volcanic rock. The only fused core which the writer has seen, which could not be recognized as such at a glance, was one which had a superficial resemblance to chert. A hasty examination in this case, however, was sufficient to disclose the presence of features 2, 3 and 4, noted below. From Ross's comments, the impression may be gained that the fused cores superficially resemble volcanic rocks of a basaltic character. On the Gulf Coast, the fused cores more often tend to resemble obsidian.

2. A tendency to a concentric circular or spiral flowage structure around the axis of rotation of the core barrel is shown by faint flowage lines and by the elongation of the bubble holes.

3. The particles of metallic iron in some cases are visible under a hand lens, and in a great many of the other cases become conspicuous if they are given a chance to rust. If it is desired, a little oil-field brine should accelerate the rusting.

4. Where fair-sized sand grains were present in the material, they remained unaltered in the fused core and usually are recognizable as sand grains. Quartz phenocrysts of course may occur in the volcanic rock, but are rather rare alone, and in the Gulf Coast cores megascopic feldspar grains are not present to simulate feldspar phenocrysts. The quartz grains in many fused cores are present in greater number than one would expect quartz phenocrysts.

When a core is well fused, the surrounding walls may be fused, and the fused material may then be encountered in later reaming.

DONALD C. BARTON

HOUSTON, TEXAS

REVIEWS AND NEW PUBLICATIONS

An Introduction to Sedimentary Petrography, with Special Reference to Loose Detrital Deposits and Their Correlation by Petrographic Methods. By HENRY B. MILNER, Lecturer in Petroleum Technology, Imperial College of Science and Technology, London. London: Thomas Murby & Co., Fleet Lane, E. C. 4; August, 1922. 5″×7½″, pp. 125. Price, 8*s.* 6*d.*, or about $2.00. New York: D. Van Nostrand & Co.

The subtitle of this useful little manual and the position occupied by the author indicate the special interest it has for oil geologists. The thoroughly scientific and critical character of the book, however, drives home the realization that it is a rather regrettable state of affairs, prevalent particularly in our own country, that a field of investigation so valuable to stratigraphers in general should at present be depending for its development mainly on the insatiable need of the petroleum industry for the application of every possible scientific resource. That the same is not true of the author's country is demonstrated by the bibliography of 82 titles—mainly the work of the author's countrymen and going back as far as a paper by Sorby in 1879—which closes the volume.

The author, while well aware of the many phases of sedimentary petrography, restricts himself in this volume mainly to the mineralogy, especially of the rarer heavy minerals of the sedimentary rocks in their bearing on paleogeography and correlation. Some 54 minerals are systematically described and a large proportion of them illustrated by figures showing their habit as they occur in sediments. In an introduction of six pages he reviews the development of the science from a mere toying with the identification of the fascinating variety of rarer minerals that occur in sediments (a stage of development not yet entirely outlived) to its use in some of the most significant problems of theoretic geology as well as in some of its most practical applications. One point in this introduction the reviewer would like particularly to emphasize. Discussing the use of microfossils, the author says (pp. 9–10): "Largely owing to the tendency of many of these organisms to have a wide distribution in space and time, the results, in so far as correlation within narrow limits is concerned, have not been as encouraging as was at first anticipated. . . . . Under these circumstances a comprehensive study of the mineralogical composition of the deposits with which oil is associated, seemed to offer, from first principles, great practical possibilities. . . . ." That is to say, the petrographic characters of rocks are likely often to permit of correlation within vertical limits closer than those indicated by the fossils.

Chapter i (14 pages) describes briefly the preparation of the material of sedimentary rocks for microscopical study—sampling, washing, treatment with

acid, crushing, heavy liquid and magnetic separations, panning, etc.—and ends with a brief outline of the microscopical examination and a summary of the optical properties of minerals. To the methods outlined here, which are simple, direct, and concisely presented, the reviewer would like to add one or two modifications. The author suggests making permanent mounts of the different concentrates, in Canada balsam. He also speaks of making concentrates of individual minerals for special chemical examination, for determination of indices of refraction by immersion in liquids of known indices, or for other tests. Thanks to the work of Wright, Larsen,[1] Merwin, and others, the use of liquids of known indices of refraction in identifying minerals has probably reached a higher state of development and taken a stronger hold in this country than in any other. The reviewer believes that by using this as a principal instead of an incidental method of identifying minerals not directly recognizable, and by making the main examination on the loose concentrates under the binocular microscope instead of on Canada balsam mounts under the petrographic microscope, the study of the minerals could be made much more flexible and more rapid. The reviewer himself used to resort to slides and the petrographic microscope and was surprised to discover how much more satisfactory it is to work with the binocular microscope. It is astonishing to find how many minerals in a lot sized between about 0.25 and 0.05 mm. (100 and 200 mesh) can, with a little practice and checking in "index" liquids, be recognized in this way; and as the field is much larger the different minerals can be picked out by the eye much more rapidly and their relative proportions estimated. It also permits of examining larger quantities of concentrate and avoids the need of as many different concentrates as in Milner's method.

In view of Cayeux's presentation of microchemical methods in the study of sedimentary rocks[2] it is not clear why Milner should say that "even microchemical reactions are inadmissible with detrital grains" (p. 22) though the use of "index" liquids and Larsen's tables should make them generally superfluous with such material.

The systematic descriptions by their different properties of the individual minerals make up the second chapter of 56 pages, the largest division of the book.

Chapters iii and iv deal with the application and more theoretic aspects of the subjects discussed in the preceding pages.

Chapter iii (18 pages) describes and illustrates in a graphic and illuminating way the use of mineralogy in differentiating and correlating stratigraphic units. But the author points out that no instructions or forms can take the

[1] See his "The Microscopic Determination of the Nonopaque Minerals," *U. S. Geol. Survey Bull. 679*, to be had *only* from the Superintendent of Documents, Washington, D.C.; price 30 cents.

[2] Cayeux, L., "Introduction à l'étude pétrographique des roches sédimentaires." Paris: *Imprimerie Nationale*, 1916, pp. 95-170.

place, in this delicate work, of skill, experience, and judgment. It is not enough merely to identify and estimate the proportion of species present; the subtle characters which distinguish them, their condition, every possible property must be used to differentiate them.

Chapter iv (8 pages) dealing with paleogeography can, as the author says, only suggest methods and problems. No resource of geologic knowledge and understanding is without its application in this, the purpose and final stage of an investigation in sedimentary petrography. It is hardly necessary to repeat to American petroleum geologists that this is as true of practical as of theoretic applications of sedimentary petrography.

So far as the reviewer's knowledge of books on sedimentary petrography goes, the last two chapters are the most original as they are also the most stimulating and suggestive. Cayeux's book, cited above, is a more extensive treatment of methods of study and of mineralogy, but it aims to cover a greater variety of petrographic methods. Milner's little manual, which is devoted primarily only to the mineralogy of disintegrated sediments, has a special value of its own on account of its very simplicity and compactness, and its vivid illustrations of the habits of different minerals. The author himself is so careful to point out that this is only a phase of sedimentary petrography, and to lay stress on the limitations and difficulties of this line of investigation, that he leaves nothing for a reviewer to add on this score. The bibliography alone makes the little book invaluable to those wishing to enter this field. But whether a beginner or more experienced worker, everyone engaged in studying the sedimentary rocks will want to have this practically useful manual ready to hand.

MARCUS I. GOLDMAN

U. S. GEOLOGICAL SURVEY

Supervision of Public Oil Lands

The United States Bureau of Mines is intrusted with supervision of mining operations on public lands leased for oil shale, phosphate, sodium, and potash. A bulletin of operating regulations has just been published by the Bureau and may be obtained upon application to the Director at Washington, D.C. A brief digest of this bulletin given in *Engineering and Mining Journal-Press* for September 2, 1922, page 421, indicates the great detail with which the government intends to supervise and safeguard all such operations.

J. H. HANCE

Drilling in Queensland

A communication from Queensland, Australia, dated August 14, and addressed to the *Engineering and Mining Journal-Press* of October 7, 1922, reviews the test drilling under way there. Considerable gas and some oil

have been found in a test well at depths of 2,815 and 3,705 feet. Drilling difficulties have been numerous, and in consequence but little headway has been made. The indications are now considered quite favorable for commercial possibilities.

J. H. HANCE

Petroleum Possibilities in Southeastern Idaho. By VIRGIL R. KIRKHAM. Bureau of Mines and Geology, Moscow, Idaho.

In the Foreword, Dean Thompson calls attention to the responsibility of the Bureau in mining problems, and concludes that there are no parts of the state other than those described which are at present recognized as geologically favorable to oil formation and accumulation. The bulletin contains detailed descriptions and separate geological reconnaissance maps for three areas; the Border area, the Phosphoria, and the Teton area, all along the Wyoming state line, in a continuation of the geological series that is oil bearing in Wyoming. Although some distance from the nearest production, the author finds no negative indications in these areas.

J. H. HANCE

Preliminary Report on Tonkawa, Oklahoma, Oil Field. By J. S. ROSS. U. S. Bureau of Mines. Issued by Bartlesville Chamber of Commerce, Bartlesville, Oklahoma.

The Bureau of Mines has ready for distribution a preliminary engineering report on the Tonkawa oil field in Oklahoma, by J. S. Ross, petroleum engineer. The Tonkawa oil field is now producing over 50,000 barrels per day of 43 gravity oil, and is the greatest producer of oil of that gravity in the United States.

At the present time 90 wells in the Tonkawa field are producing at the average rate of 550 barrels per well per day. In addition some 125 wells are now in course of drilling. In view of these facts and the numerous producing horizons it is possible that within the next few months Tonkawa will become the largest producing field in Oklahoma, unless the new extension to the Burbank field results in keeping that field in the lead.

The Tonkawa field, which is located in T. 24 and 25 N., R. 1 W., Kay and Noble counties, north central Oklahoma, was discovered in June, 1921, by the Marland Refining Company.

The preliminary report, which is about twenty-five mimeographed pages in length, deals with underground conditions, methods of drilling, casing programs, protection of oil and gas measures, and the production and disposition of the oil and gas. Chemical analyses of oil samples, as well as gas and water samples from various sands, are included.

The paper is accompanied by three engineering cross-sections through the Tonkawa field, and a structure contour map of the field.

This report is being distributed by the Bartlesville Chamber of Commerce at a price of $1.00 per copy.

RAYMOND C. MOORE

Stratigraphy of the El Dorado Oil Field, Arkansas, as Determined by Drill Cuttings. By JAMES GILLULY and K. C. HEALD. Bulletin 736-H., United States Geological Survey (February 9, 1923), Washington, D.C.

This is a report of seven pages and one plate whose purpose is to describe by drill cuttings the stratigraphic column at El Dorado, "in order to facilitate development in the field and to furnish a guide to oil operators prospecting in surrounding territory."

The formations are described from cuttings and core samples taken at 10-foot intervals from one well located in the northwest edge of the field. The formations in this well may be fairly representative of the shallow producing field, but as no cuttings were kept below 2,143 feet, the producing formation itself is not described, nor is any formation mentioned below the Nacatoch, although many wells have been drilled to deeper sands. To this extent, therefore, the report fails in describing the stratigraphy of the El Dorado oil field.

An enlightening study of the formations is made by a graphic comparison of three logs of the one well, namely: a log showing percentage of sand, clay, and limestone found in cuttings, another log made from the lithologic character and fossil content of the cuttings, and a third log as kept by the driller.

The St. Maurice clays are not shown in the driller's log, only sand and bowlders having been recorded. This illustrates the great importance of checking the driller's log by geologic examination of cuttings.

The report shows the valuable use of percentages of physical constituents and fossil content of carefully taken cuttings.

It is, as stated, a guide to drilling, but it is essentially an argument for microscopic and paleontologic geology in the correlation of formations.

J. P. D. HULL

SHREVEPORT, LOUISIANA
March 7, 1923

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to Charles E. Decker, Norman, Oklahoma.

(Names of sponsors are placed beneath the name of each applicant.)

FOR FULL MEMBERSHIP

Gerard E. Ebmeyer, Tulsa, Oklahoma
Jon A. Udden, Dugald Gordon, James E. Hoover

Robert W. Phelps, Brea, California
William S. W. Kew, Carroll M. Wagner, Wayne Loel

James D. Thompson, Jr., Amarillo, Texas
Thomas T. Harrison, L. C. Snider, A. W. McCoy

H. G. Schneider, Shreveport, Louisiana
Sidney Powers, Angus McLeod, L. P. Teas

Donald E. Hageman, San Diego, California
E. G. Sinclair, C. Max Bauer, H. T. Morley

Stanley E. Slipper, Calgary, Alta., Canada
O. B. Hopkins, E. W. Owen, F. A. Davies

Gerald A. Waring, Trinidad, British West Indies
K. C. Heald, E. DeGolyer, P. Charteris A. Stewart

Gail F. Moulton, Vermillion, South Dakota
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Vernon L. King, Los Angeles, California
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Kenneth B. Nowels, Salt Creek, Wyoming
C. A. Fisher, R. Van A. Mills, Carroll H. Wegemann

Frank S. Hudson, Los Angeles, California
William S. W. Kew, E. F. Davis, Carroll M. Wagner

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James S. Stewart, Toronto, Ontario, Canada
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Wallace E. Pratt, D'Arcy M. Cashin, W. E. Wrather
H. Norman Snively, Rawlins, Wyoming
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Sidney Powers, Burton Hartley, C. R. Thomas
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Elmslie T. Thomas, Fayetteville, Arkansas
Gilbert H. Cady, U. S. Grant, J. H. Hance
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R. E. Collom, Charles L. Baker, E. G. Gaylord
Frederick G. Tickell, Palo Alto, California
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Rebecca B. Masterson, Houston, Texas
David Donoghue, Wallace E. Pratt, R. F. Baker
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John. A. Egan, Tulsa, Okla.
E. F. Schramm, Jack M. Sickler, L. O. Whyman
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Roger Fleming White, Washington, D.C.
Lisle R. Van Burgh, John Cullen, Clarence Z. Logan
Warren N. Thayer, Washington, D.C.
John Cullen, L. R. Van Burgh, Clarence Z. Logan
Everett C. Edwards, Tampico, Mex.
W. H. Twenhofel, Clifton S. Corbett, Charles E. Decker
Elton Rhine, Shreveport, La.
Sidney Powers, Chester C. Clark, Angus McLeod
R. J. Takahashi, Sendai, Japan.
Sidney Powers, Dean E. Winchester, J. L. Gartner
Henry S. Rade, Shreveport, La.
W. C. Spooner, S. C. Stathers, J. P. D. Hull

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Earl E. Marshall, Okmulgee, Oklahoma
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Clarence W. Hoffer, Austin, Tex.
H. P. Bybee, J. A. Udden, E. H. Sellards
Elmer A. Markley, Guthrie, Okla.
Robert H. Wood, Virgil O. Wood, D. W. Ohern
Robert L. Cannon, Mineral Wells, Tex.
E. Russell Lloyd, Grady Kirby, Urban B. Hughes
Richard T. Bright, Tulsa, Okla.
Jon A. Udden, L. G. Huntly, Paul Ruedemann
Phil K. Cochran, Tulsa, Okla.
C. S. Corbett, R. C. Moore, R. S. Knappen

Wallace Ralston, Colorado Springs, Colo.
C. E. Decker, R. C. Moore, R. S. Knappen
Albert H. Richards, Enid, Okla.
Claude F. Dally, S. G. Garrett, V. E. Monnett

MEETING OF THE SOCIETY OF ECONOMIC GEOLOGISTS

Mr. S. H. Ball, secretary of the Society of Economic Geologists, has written extending a cordial invitation to the members of the association to attend the technical sessions of the Economic Geologists at their meeting in New York City May 18 and 19, 1923.

THE SHREVEPORT MEETING

The Eighth Annual Meeting of the American Association of Petroleum Geologists which was held at Shreveport, Louisiana, March 22, 23, and 24, is now history. The following informal account is published in the *Bulletin* for the benefit of members who were unable to be present at this gathering of the clans and to enjoy the technical and social activities of the sessions.

As noted by the local press, the "best minds" were present in large numbers the evening before the opening addresses of welcome. Certainly it was already difficult to obtain hotel accommodations. Our gathering was reported to be the largest and most important which has been held in Shreveport and much attention was given by the city to the occasion. The committee of Shreveport geologists had labored tirelessly to make all arrangements for the meetings and for the entertainment of visiting geologists the best possible. Sufficiently cordial appreciation of the work done by all divisions of the local committee it was hardly possible to express in the formal resolutions read and passed at the close of the meetings. In addition to the customary scientific sessions, the smoker, and the annual banquet, a delightful program of entertainment for visiting ladies was carried out, and opportunities for geological field trips to neighboring oil fields were planned. It was a regret to most that the long program of scientific papers and the accompanying discussion so filled the available time that it was impossible within the three days of the meetings to undertake any trips to near by fields.

The headquarters of the convention and all of its meetings were in the Youree Hotel. The ballroom of the hotel afforded very satisfactory accommodations for the presentation of papers and in it were held the smoker and banquet. The hospitality and interest of the city of Shreveport were well expressed by Mayor L. E. Thomas; the welcome of Shreveport and Louisiana geologists by Ben K. Stroud, general chairman of the local committee. Response to these greetings was expressed by President W. E. Wrather. The large room was filled when the first paper, initiating consideration of the Coastal Plain region, was begun. No comment on the various papers or discussion can well be included here, though the program is recorded below. As usual in the meetings

of the Association, the value of the papers read and the discussions made was indicated by the sustained interest and large attendance at all of the sessions. The papers will subsequently appear in the *Bulletin*.

The smoker afforded varied entertainment as well as much smoke and some indigestion, but as guests were seated at tables throughout the meeting, the desirable opportunity for "mixing,"—a thing increasingly needed as our Association continues its extraordinary growth,—was lacking. However, there was considerable pleasant chance for this between sessions down in the lobby. Mr. Gallagher and Mr. Shean, the former represented by R. W. Brown and the latter strongly a la J. Elmer Thomas, made a hit, with lyrics specially written for the occasion, and divided somewhat hilarious acclamation with an unusually accomplished terpsichorean product of the Shreveport high schools, Miss Gillespie.

The banquet, space requirements for which almost overtaxed the large ballroom, was especially enjoyable not only by reason of gustatorial elements which are supposed to be offered, but because of the unusual character of the program presided over by Toastmaster J. Elmer Thomas. Clever skits including some funeral obsequies directed by Ben Stroud and a drama written by Max Ball provided much amusement. Hardly suspected Thespian ability was brought to light in the inimitably realistic characterization of beautiful Queen Cleopatra by E. Russell Lloyd, of Egyptian lease grafters by Perrine and Frank Herald, of antediluvian geologists by Ryan and Nelson, and of the queen's attendant by Frank Edson.

The business sessions, to be reported officially by the secretary in the next number of the *Bulletin*, were held Friday and Saturday mornings. President Wrather's report indicated the accomplishment of important Association objectives during his administration and contained valuable recommendations concerning policies and future work. Secretary-Treasurer C. E. Decker announced that membership in the Association had increased during the year to more than 900 and that applications not yet approved will shortly bring the total membership to more than 1,000. The finances of the Association are in excellent condition with a considerable balance in hand. The editor, Raymond C. Moore, explained new arrangements for publication of the *Bulletin* and for binding. Reports of special and standing committees and action concerning them by the Association will be recorded in the *Bulletin* by the secretary. For the presidency of the Association Max W. Ball and James H. Gardner were nominated, a close vote resulting in the election of Mr. Ball. Frank de Wolf, who has recently become chief geologist for the Humphreys Company, was nominated and elected vice-president without opposition. The incumbent secretary-treasurer and editor were re-elected.

Altogether the geologists who attended the Shreveport meeting seem to have had a splendid time and, as in the case of each previous meeting, the gathering may be recorded as one of the most successful in the history of the organization.

PROGRAM OF THE SHREVEPORT MEETING

Hotel Youree, Shreveport, Louisiana

THURSDAY MORNING, 10:00–12:00

Greetings—HON. L. E. THOMAS, mayor of the city.
Greetings—BEN K. STROUD, for the local geologists.
Response—W. E. WRATHER, president.

COASTAL PLAIN REGION

(Alabama, Arkansas, Louisiana, Mississippi)

J. E. BRANTLY—Regional Geology of the Gulf Coastal Plain.
G. I. ADAMS—The Oil and Gas Possibilities of Alabama.
JON UDDEN—Oil Prospects in Alabama.
P. F. MORSE—Petroleum Prospecting in Mississippi.
J. P. D. HULL—Stratigraphy of Producing Sands in Louisiana and Arkansas.
A. F. CRIDER—The Relation of Cretaceous and Eocene Structures in Louisiana and Arkansas.
L. P. TEAS—Differential Compacting the Cause of Certain Claiborne Dips.
H. A. LEY—A Relation of the Quality of Oil to Structure in El Dorado, Arkansas.

THURSDAY AFTERNOON, 2:00–5:00

G. R. STEVENS—The Smackover Old Field, Arkansas.
H. W. Bell—Subsurface Conditions in the Smackover Oil Field.
H. K. SHEARER—The Stephens Field, Arkansas.
W. C. SPOONER and S. C. STATHERS—The Homer Oil Field, Louisiana.
W. C. SPOONER—The Pine Island Pool, Louisiana.
E. HOLMAN and R. B. CAMPBELL—The Bellevue Oil Field, Louisiana.
BEN K. STROUD and F. P. SHAYES—The Monroe Gas Field, Louisiana.
G. M. PONTON, GEORGE BELCHIC, C. A. BREITUNG, and J. W. WHITEHURST—The Springhill-Sarepta Field, Louisiana. (Introduced by BEN K. STROUD.)

TEXAS

R. B. WHITEHEAD—The Tehuacana and Other Faults of East Central Texas.
R. A. JONES—The Relation of the Reynosa Escarpment to the Oil and Gas Fields of Webb and Zapata Counties, Texas.
C. A. HAMMILL—The Bethany Gas Field.
M. G. CHENEY—Correlation of Producing Cisco, Strawn and Bend Sands of Young County, Texas.
M. G. CHENEY—Relation of Surface Structure to Subsurface Structure and Production in the Bunger Field, Young County, Texas.
F. C. DODSON—General Geology of the Mitchell-Howard County District, Texas.

THURSDAY EVENING, 8:00

Smoker—Gold Ballroom, Hotel Youree.

FRIDAY MORNING, 9:00–11:00

MEXICO

E. DEGOLYER—The Occurrence of Oil in Mexico.

E. A. TRAGER—The General Geology of the Panuco District of Mexico.

J. A. CUSHMAN and E. A. TRAGER—Preliminary Notes Concerning the Upper Cretaceous of the Panuco District of Mexico.

MID-CONTINENT

C. W. HONESS—The Geology of Southern LeFlore and Northwestern McCurtain Counties, Oklahoma.

G. C. CLARK and F. L. AURIN—The Tonkawa Oil Field, Oklahoma.

G. H. GIRTY and P. V. ROUNDY—Notes on the Glenn Formation, Oklahoma.

A. W. MCCOY—Geological Notes on Some Producing Sands of the Western Cherokee Basin.

J. B. UMPLEBY—Some Fossil Oil Pools in the Simpson Formation near Sulphur, Oklahoma.

C. K. CLARKE—The Oil Business from an Executive's Point of View.

J. B. ELAM—The Right Relation of the Oil Industry to the Public.

BUSINESS MEETING, 11:00–12:30

FRIDAY AFTERNOON, 2:00–5:00

K. C. HEALD—The National Research Council and Oil Geology.

G. D. MORGAN—The Relations of the Franks and Seminole Conglomerates of Oklahoma. Presented by A. E. Brainerd.

MRS. F. A. EDSON—Bibliography of the Simpson formation.

R. W. SAWYER—The Relation of the Enid and the Overlying Formation in Southern Oklahoma.

A. R. DENISON—The Subsurface Geology of the Robberson Oil Field, Oklahoma.

HARVE LOOMIS—Conditions in the Burkett Pool of Greenwood County, Kansas.

J. M. SANDS—Recently Developed Pools of Butler and Greenwood Counties, Kansas.

A. W. MCCOY and W. K. CADMAN—Mississippi Lime in Greenwood County, Kansas.

W. A. NELSON—Description of Oil and Gas Horizons in Kentucky, Tennessee, and Northeastern Mississippi.

E. BECK—Possibilities for Oil in the Lake Basin District, Montana.

R. A. WILSON—Superficial Structures in South Dakota.

H. V. HOWE—The Fossil Markers of the Pacific Coast Tertiary.

O. M. EDWARDS—Geology of Ship Rock Basin, Northwestern New Mexico.

W. H. TWENHOFEL—The Negligible Possibilities for Oil in Wisconsin.

FRIDAY EVENING, 7:30

Annual Informal Dinner, Gold Ballroom, Hotel Youree.

SATURDAY MORNING, 9:00–10:30

SALT DOMES

W. F. HENNIGER—The Occurrence of Sulphur Waters in the Gulf Coast of Texas and Louisiana and Their Significance in Locating New Salt Domes.

H. E. MINOR—The Chemical Relations of Salt Dome Waters.

C. E. HYDE—Salt Domes of the Rio Grande Region.

T. W. VAUGHAN—On the Relative Value of Smaller Foraminifera in the Recognition of Stratigraphic Zones.

A. C. KNAPP—The Present Situation in the Oil Industry.

J. E. PEW—The Oil Industry—Its Importance and Some of Its Problems.

BUSINESS SESSION, 10:30–12:00

SATURDAY AFTERNOON, 2:00–5:00

SIDNEY POWERS—Structural Classification of Oil and Gas Fields.

A. F. MELCHER—Texture of Oil Sands.

E. L. ESTABROOK—Analysis of Wyoming Oil Field Waters.

J. L. RICH—Notes on the Gravity of Oil in Relation to Water Circulation.

C. H. WEGEMANN—Influence of Water Circulation on the Accumulation of Petroleum.

R. H. JOHNSON—Naming Oil Sands and Pools.

R. H. JOHNSON—Appraisal for Purchase in Distinction from That for Other Purposes.

JOSEPH SEEP—The Geographical and Geological Distribution of the Named Grades of Petroleum of the Eastern Fields. (Introduced by R. H. Johnson.)

R. W. BROWN—Analysis of Tract Production.

J. B. EBY—The Possibilities of Oil and Gas in Southwest Virginia as Inferred by Isocarbs. (Introduced by K. C. Heald.)

R. C. COFFIN—Notes on the Geology of Southwestern Colorado and Adjacent Areas.

D. E. LOUNSBERY—Oil Possibilities in India.

F. W. DEWOLF and D. M. COLLINGWOOD—Structure of Porcupine Dome, Montana.

DAVID WHITE—Some Gravity Observations in Mid-Continent and Gulf Coast.

CHAIRMEN OF LOCAL COMMITTEES

BEN K. STROUD, General Chairman; J. E. BRANTLY, Program; H. D. EASTON, Hotels and Auditorium; E. HOHMAN, Reception; A. MCLEOD, Entertainment, G. R. STEVENS, Banquet; MRS. CLYDE M. BENNETT, Entertainment for Ladies.

Registered at the Meeting

A list, not complete, of those attending the meeting follows: Adams, George I., Tuscaloosa, Alabama; Allen, W. J., Tulsa, Oklahoma; Ames, E. W., Cisco, Texas; Applin, P. L., Shreveport, Louisiana; Aurin, F. L., Ponca City, Oklahoma.

Baker, R. F., Houston, Texas; Ball, Max W., Denver, Colorado; Barrow, L. T., Austin, Texas; Barton, Donald C., Houston, Texas; Barton, Louis A., Cleveland, Ohio; Bartram, John G., Ardmore, Oklahoma; Bauer, C. Max, Billings, Montana; Bell, H. W., Dallas, Texas; Bennett, Clyde M., Shreveport, Louisiana; Berger, W. R., Ponca City, Oklahoma; Bevier, George M., Houston, Texas; Bierman, A. C., New York City; Blanchard, J. B., San Antonio, Texas; Borden, S. P., Shreveport, Louisiana; Bourman, W. F., Houston, Texas; Brace, Orval L., El Dorado, Arkansas; Brainerd, A. E., Holdenville, Oklahoma; Brantly, J. E., Shreveport, Louisiana; Brown, J. E., San Antonio, Texas; Brown, R. W., Shreveport, Louisiana; Buttram, Frank, Oklahoma City, Oklahoma; Burg, Robert S., Fort Worth, Texas; Bybee, H. P., Austin, Texas.

Campbell, R. B., Shreveport, Louisiana; Cashin, D'Arcy M., Houston, Texas; Caudill, S. J. C.; Clark, C. C., Shreveport, Louisiana; Clark, Glenn C., Ponca City, Oklahoma; Closuit, E. M., Fort Worth, Texas; Conkling, R. A., Oklahoma City, Oklahoma; Cook, C. E., Austin, Texas; Crider, A. F., Shreveport, Louisiana.

Dallas, Orlan L., Fort Worth, Texas; Darnell, J. L., New York City; Davis, E. F., San Francisco, California; Day, Clarence O., Shreveport, Louisiana; Deussen, Alexander, Houston, Texas; DeWolf, F. W., Dallas, Texas; Dorchester, C. M., Shreveport, Louisiana; Donoghue, David, Fort Worth, Texas; Douglas, J. M., Denver, Colorado; Drake, N. F., Fayetteville, Arkansas; Duston, A. W., Okmulgee, Oklahoma.

Easton, H. D., Shreveport, Louisiana; Edson, Dwight J., Mexia, Texas; Edson, Fanny C., Norman, Oklahoma; Edson, Frank A., Norman, Oklahoma; Edwards, O. M., Tulsa, Oklahoma.

Ferguson, John L., Oklahoma City, Oklahoma; Fohs, F. Julius, New York City; Frost, Jack, Dallas, Texas; Fuqua, H. B., Wichita Falls, Texas.

Gardner, J. H., Tulsa, Oklahoma; Garrett, L. P., Houston, Texas; Gaylord, E. G., San Francisco, California; Gester, Stephen H., San Francisco, California; Geyer, F. P., Ponca City, Oklahoma; Gish, Wesley G., Wichita, Kansas; Gouin, Frank, Duncan, Oklahoma; Gould, Charles N., Oklahoma City, Oklahoma; Gray, Alfred, Shreveport, Louisiana.

Hamilton, H. L., Houston, Texas; Hamilton, W. R., Tulsa, Oklahoma; Hares, C. J., Denver, Colorado; Harlowe, L. S., Shreveport, Louisiana; Harnsberger, T. K., Tulsa, Oklahoma; Harrison, T. S., Denver, Colorado; Hartman, Adolph E., Fort Worth, Texas; Hay, L. C., Dallas, Texas; Heald, K. C., Washington, D. C.; Henley, A. S., Houston, Texas; Henniger, W. F.,

Houston, Texas; Henning, J. L., Lake Charles, Louisiana; Herald, F. A., Tampico, Mexico; Honess, C. W., Norman, Oklahoma; Hopkins, E. B., New York City; Hopper, W. E., Shreveport, Louisiana; Howe, H. V., Baton Rouge, Louisiana; Howell, J. V., Ponca City, Oklahoma; Hughes, U. B., Dallas, Texas; Hummel, E. W., Mountain View, Oklahoma.

Johnson, R. H., Pittsburgh, Pennsylvania; Jones, R. A., Laredo, Texas; Justice, P. S., Beaumont, Texas.

Kennedy, William, Dallas, Texas; Kerr, J. B., Shreveport, Louisiana; Kew, William S. W., Los Angeles, California; Kirby, G., San Antonio, Texas; Kirk, C. T., Tulsa, Oklahoma; Kite, W. C., Oklahoma City, Oklahoma; Knapp, Arthur, Philadelphia, Pennsylvania; Kniker, Hedwig T., Houston, Texas; Kraus, Edgar, Houston, Texas.

Lahee, Frederic H., Dallas, Texas; Ley, H. A., Independence, Kansas; Lloyd, E. R., Denver, Colorado; Lowe, E. N., Jackson, Mississippi; Lynton, E. D., Los Angeles, California.

Markham, E. O., Tulsa, Oklahoma; Matson, G. C., Tulsa, Oklahoma; McCluer, R. D., Corsicana, Texas; McFarland, R. A., Tulsa, Oklahoma; McLaughlin, H. C., Dallas, Texas; McLeod, Angus, Shreveport, Louisiana; Melcher, A. F., Washington, D.C.; Mendenhall, W. C., Washington, D.C.; Miller, F. J., Shreveport, Louisiana; Millikan, C. V., Tulsa, Oklahoma; Moody, C. L., Shreveport, Louisiana; Moore, Raymond C., Lawrence, Kansas; Morgan, G. B., Cheyenne, Wyoming; Morse, P. F., A. & M. College, Mississippi; Morse, W. C., A. & M. College, Mississippi; Myers, J. C., Greeley, Colorado; Nelson, W. A., Nashville, Tennessee.

Ohern, D. W., Oklahoma City, Oklahoma.

Parker, E. C., Ponca City, Oklahoma; Pellekaan, W. Van Holst, Tulsa, Oklahoma; Pepperberg, L. J., Dallas, Texas; Perrine, Irving, Oklahoma City, Oklahoma; Plummer, F. B., Houston, Texas; Powers, Sidney, Tulsa, Oklahoma; Pratt, W. E., Houston, Texas; Preece, Rae, Tulsa, Oklahoma.

Rade, H. S., Shreveport, Louisiana; Rath, C. M., Denver, Colorado; Reed, L. C., Houston, Texas; Reed, W. B., Morgan City, Louisiana; Richards, Esther E., Houston, Texas; Riggs, R. J., Tulsa, Oklahoma; Roark, E. L., Ponca City, Oklahoma; Ross, J. C., Tulsa, Oklahoma; Row, C. H., Dallas, Texas.

Sands, J. M , Bartlesville, Oklahoma; Sawtelle, George, Houston, Texas; Sawyer, Roger W., Oklahoma City, Oklahoma; Schoolfield, R. F., Shreveport, Louisiana; Schroyer, C. R., San Antonio, Texas; Scott, W. W., Shreveport, Louisiana; Sealey, F. C., Houston, Texas; Segall, Julius, Minneapolis, Minnesota; Sellards, E. H., Austin, Texas; Shearer, H. K., Shreveport, Louisiana; Sheldon, Grace R., Wichita Falls, Texas; Shoults, C. S., Dallas, Texas; Smoots, J. P., El Dorado, Arkansas; Snider, L. B., Tulsa, Oklahoma; Snow, D. R., Tulsa, Oklahoma; Snyder, J. Y., Shreveport, Louisiana; Spooner, W. C., Shreveport, Louisiana; Stander, A. E., Tulsa, Oklahoma; Stathers, S. C.,

Shreveport, Louisiana; Stephenson, C. D., Pawhuska, Oklahoma; Stevens, G. R., Shreveport, Louisiana; Stroud, Ben K., Pittsburgh, Pennsylvania; Studt, C. W., Yates Center, Kansas; Suman, J. R., Houston, Texas; Taff, J. A., Palo Alto, California.

Taylor, C. H., Oklahoma City, Oklahoma; Leas, L. P., Shreveport, Louisiana; Thomas, C. R., Tulsa, Oklahoma; Thomas, J. E., Chicago, Illinois; Thompson, W. C., Dallas, Texas; Tomlinson, C. W., Ardmore, Oklahoma; Vaughan, F. E., Lake Charles, Louisiana.

Wagener, C. H., Dallas, Texas; Washburne, C. W., New York City; Wegemann, C. H., Denver, Colorado; White, David, Washington, D.C.; White, L. H. T., Tulsa, Oklahoma; Whitehead, R. B., Shreveport, Louisiana; Whitney, F. L., Austin, Texas; Wilson, Joseph M., Fort Worth, Texas; Wilson, M. E., Shreveport, Louisiana; Woolsey, E. V., Dallas, Texas; Wrather, W. E., Dallas, Texas.

RAYMOND C. MOORE

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

P. CHARTERIS A. STEWART, whose death by drowning January 14, 1923, while bathing at Balandra Bay, Trinidad, B.W.I., has recently been reported, was well known as a geologist and petroleum technologist. At the time of his death he had been connected for nearly twenty years with Viscount Cowdray's firm, Messrs. S. Pearson & Son, Limited, and had been closely associated with them in their oil enterprises. Before that he was on the staff of the Egyptian Government Geological Survey. He had traveled extensively in the course of his work, and was a member of many learned societies, among others being the Royal College of Science, the Geological Society, the Institution of Petroleum Technologists, and the American Association of Petroleum Geologists. His death at the age of forty-eight has cut short a promising career, and his loss will be keenly felt not only by his friends, but by all connected with the British petroleum industry.—*Extract from "Times" dated January 22, 1923.*

H. W. C. PROMMEL, for the past five years with Fisher and Lowrie, of Denver, has opened an office as consulting engineer and geologist at Room 526, First National Bank Building, Denver, Colorado.

J. M. DOUGLAS is now employed exclusively by the Union Oil Co. of California, directing that company's geological work in the Rocky Mountain states from his office, 605 E and C Building, Denver, Colorado.

C. B. OSBORNE, chief geologist of the Homestake Exploration Co., Great Falls, Montana, is spending several months in southern California. Address: Care of Raymond G. Osborne, Marsh-Strong Building, Los Angeles.

J. M. Sickler, formerly with the California Co. at Billings, Montana, is now with the Union Oil Co. of California, address Union Oil Building, Los Angeles.

E. A. FROYD, the Midwest Refining Co.'s resident geologist at Salt Creek, is representing Natrona County in the lower house of the present Wyoming legislature.

L. R. VAN BURGH, former associate of C. T. Lupton, and geologist for the Ute Petroleum Co., Plateau Oil Co., and other companies in Denver, is now valuation engineer, Income Tax Unit, Room 5010 Interior Building, Washington, D.C.

C. T. LUPTON, formerly consulting geologist for the Mutual Oil Co. and allied companies of Denver, has opened an office at 1029 First National Bank Building, Denver, Colorado, as petroleum geologist.

T. S. HARRISON, on February 1, 1923, became consulting geologist for the Mutual Oil Co., and will also maintain his office as petroleum geologist, 706 First National Bank Building, Denver, Colorado.

E. RUSSELL LLOYD is to be chief geologist of the Marine Oil Co., with headquarters in Denver, Colorado. Mr. Lloyd was formerly with the United States Geological Survey, and later with the Sinclair-Wyoming Oil Co. For the past two years he has been chief geologist of the Mid-Kansas Oil Co., with headquarters at Mineral Wells, Texas.

W. TAYLOR THOM, JR., has been appointed geologist in charge of the coal section of the U. S. Geological Survey, effective February 1. He succeeds Marius R. Campbell who, after many years' efficient service in this position, has been relieved in order that he may devote his attention to physiographic work.

C. W. STUDT is with the Producers and Refiners Corporation with headquarters at Yates Center, Kansas.

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